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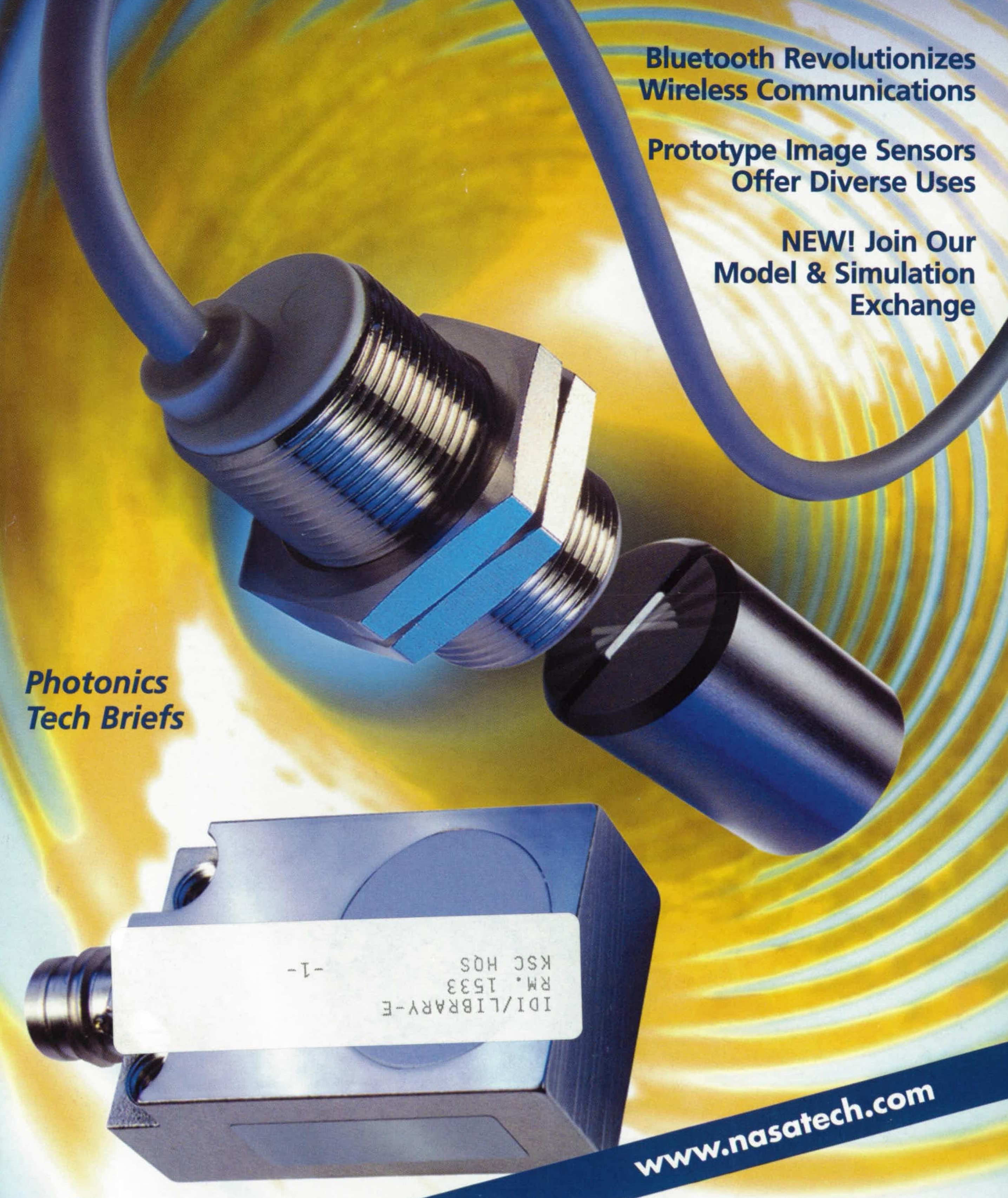

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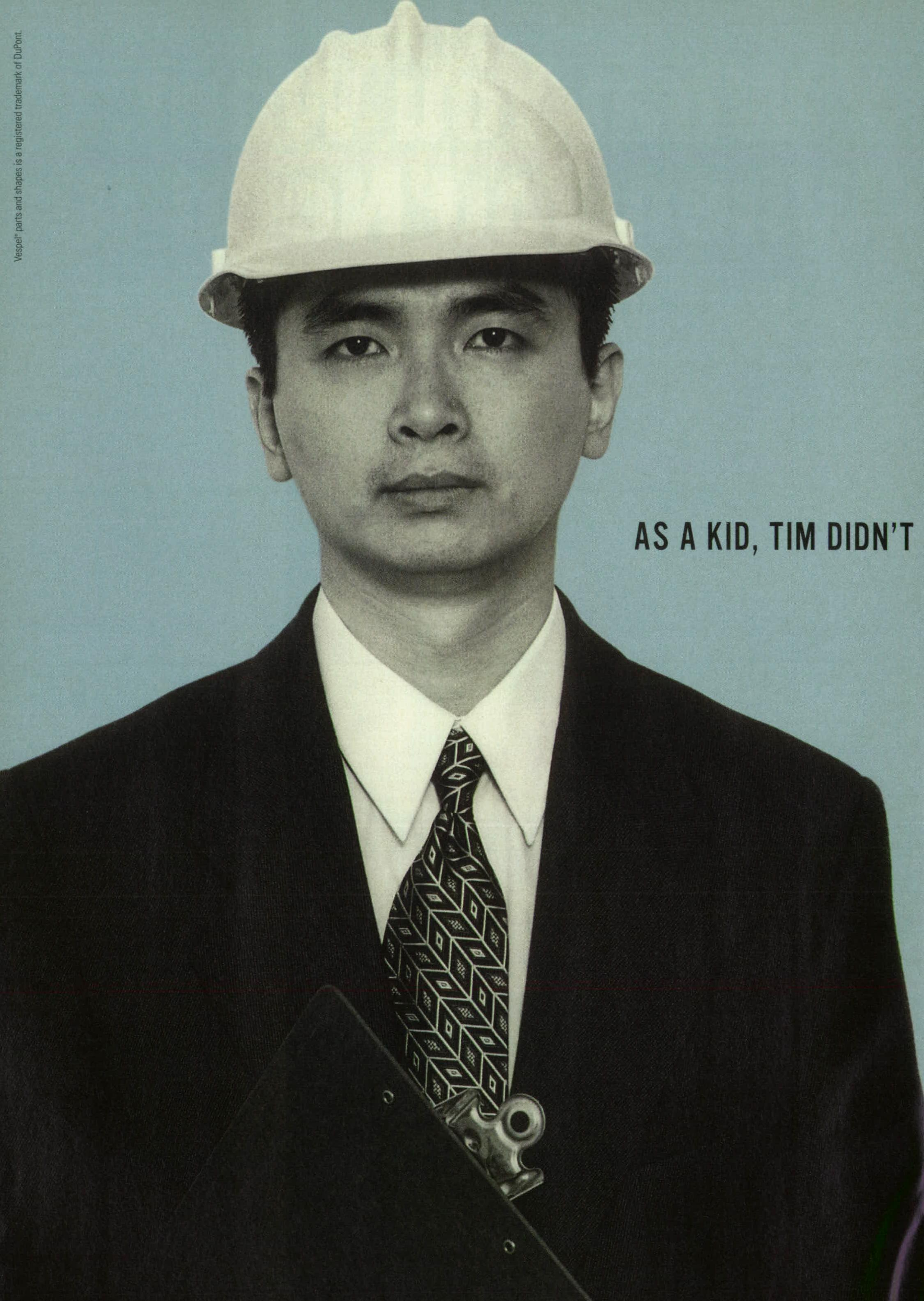
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ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING
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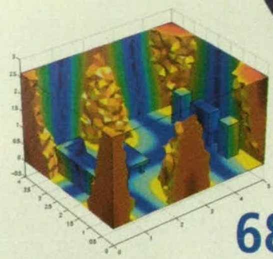
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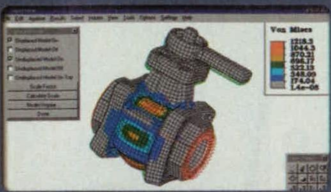
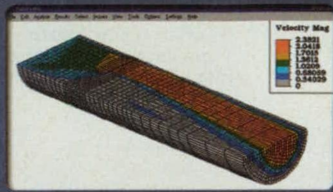
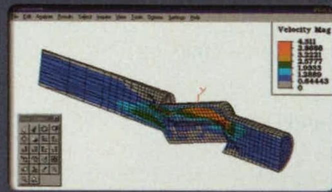
12 Reasons Why Algor Should Be Your FEA Partner



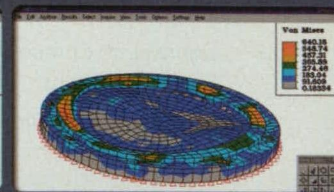
Linear Static Stress - Algor's linear static stress product enables you to capture complex assemblies, such as this valve assembly, from a CAD solid modeler and run a finite element analysis using fast solver technology. Typical loadings are pressure, acceleration, temperature, force and prescribed displacements.



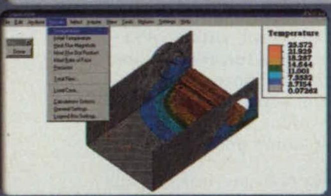
Steady Fluid Flow - Prescribed velocities and pressures provide the loading for this 3-D steady fluid flow analysis of a pipe with a gate valve. Algor's multiple load curves allow for easy data entry for adding loading such as gravity.



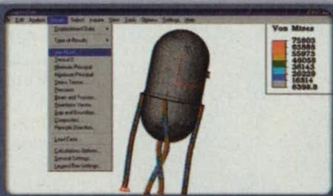
Unsteady Fluid Flow - Unsteady fluid flow of this ball valve system was analyzed using a 3-D CAD solid model. Algor's unique processor solves for velocities and pressures throughout the dynamic event, using a specialized meshing algorithm for high velocity gradients.



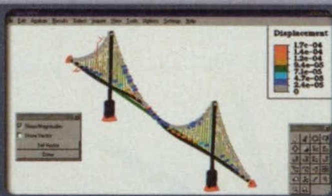
DDAM - Algor's Dynamic Design Analysis Method enables you to analyze the shock response at the mountings of shipboard equipment such as watertight doors, masts, propulsion shafts, rudders, exhaust uptakes and portholes, as shown above.



Transient Heat Transfer - The dynamic effects of a transient heat transfer analysis were needed for the time-dependent temperature loading of this heat sink assembly. Algor's multiple load curves for various loading conditions allow for the simulation of the thermal event.



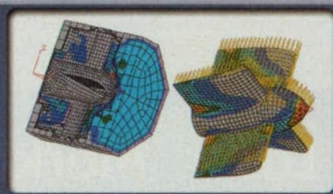
Nonlinear Static Stress - Algor's nonlinear product helps to accurately predict large deformation and large strains caused by static loading. As seen by this water tank, buckling of a structure is one type of failure that can be exposed.



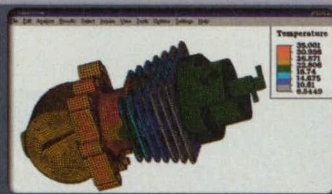
Linear Dynamic Stress- A modal analysis is one of the linear dynamic stress analyses performed on this suspension bridge. Failure can occur when the loading frequency is at the structure's resonant frequency. Algor's linear dynamic analyses accurately predict these frequencies and dynamic effects.

Mechanical Event Simulation (MES) with Nonlinear Material Models - Algor's MES extends full dynamic analysis capabilities to large strain/deformation analyses of nonlinear materials, as shown by this landing gear assembly. Kinematic elements can be used for quicker processing.

Mechanical Event Simulation (MES) with Linear Material Models - Algor's MES with linear material models allows you to represent a dynamic analysis while solving for kinematics, deflections and stresses of the structure. Analyses using large CAD assemblies, such as this rocker arm assembly model, can be expedited by using kinematic elements.



Multiphysics - Algor's multiphysics products enable you to combine multiple analysis types into one event. Resultant forces from flow around this turbine were calculated and then projected onto the object for a structural analysis. Other multiphysics capabilities include combining heat transfer with fluid flow, heat transfer with static/transient stress and heat transfer with fluid flow and stress.



Steady-State Heat Transfer - Algor's steady-state thermal processor helps predict temperature distribution due to thermal loading. Loading such as convection, radiation, conduction, applied temperatures and surface heat fluxes can be added to an analysis for fast, accurate results. In the case of this engine casing, both conduction and convection were part of the analysis of this 3-D solid model.

Piping Design and Analysis - Algor's piping design and analysis product enables you to calculate the deflections and stresses of this plant piping system and then compare the results with ASME/ANSI code allowables. Loadings can include: dead weight, thermal differences, pressure, wind loads, earthquake loads, time history of forces/displacements, response spectrum, natural frequencies and pitch and roll.

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PRODUCT OF THE MONTH

thinkdesign 6.0 3D CAD software from think3, Santa Clara, CA, offers a new speech-enabled graphical user interface and a variety of advanced 3D functions.

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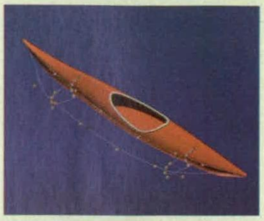

ON THE COVER

This month's Special Coverage on Sensors features new sensor products such as the MDRM magnetic sensor from Baumer Electric, Southington, CT (page 42). The sensor, with analog output, is designed for use as a non-contact mechanical potentiometer in motion control applications. For more sensor innovations, see the special coverage beginning on page 36.

(Image courtesy of Baumer Electric)

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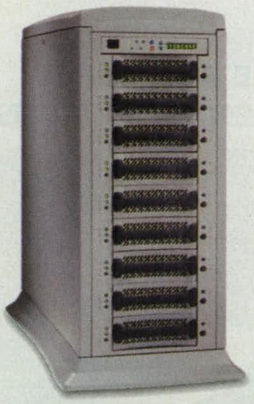

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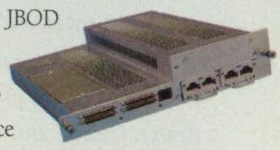

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I have some suggestions for A.A. Pallacios Collins, who asked about a portable device that would register the amount of liquid inside a beer keg for his liquor auditing company (Reader Forum, October 2000). First, if you tip the keg slightly, you can slide a small L-shaped bracket with a load cell under the high side, and read half of the total weight. Second, you can purchase a relatively inexpensive thermometric flat display designed for measuring propane left in gas grill propane tanks. The demarcation line between the fluid and the air generally has a temperature differential.

Henry L. West
West Consulting
hlwest@juno.com

The October 2000 Reader Forum column featured a letter from Norton Pierce discussing electrochemical batteries as an alternative to conventional storage batteries for wheelchair battery chargers. Non-acid-based batteries have been in use since the First World War, in which they were used in Navy submarines. They are also referred to as "Edison Cells" for their inventor. They are nickel metal hydroxide material and can be rapidly charged and discharged without damage. Toyota is now using a similar battery of nickel metal hydride in their hybrid gas-electric vehicle. This is probably the type of battery Mr. Pierce was referring to.

Lloyd A. Buchalter, ME
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West Point, NY
914-938-4976

I work for an electrical connector manufacturer in Manchester, NH. Currently, I am working on a project to design a new high-temperature insulated wire connector for the aerospace industry. An engineer in my office recalls seeing an article in *NASA Tech Briefs* describing problems associated with wire insulation containing fluoroethylene. The problems dealt with the chemical outgassing corroding the nickel and nickel-plated electrodes. This is a serious problem, and I need to avoid these types of insulation. Can you help me find the text of this article? Thank you.

Andy Zwit
Project Manager
FCI USA
azwit@fciconnect.com

*(**Editor's Note:** Andy, the article you refer to appeared in the October 2000 issue of* NASA Tech Briefs. *A copy of the article, "A Tale of Corrosion in Sealed Connector Bags," is on its way to you. In the meantime, you can contact the author of the article, Cristi Cristich of Cristek Interconnects at 714-618-2001; e-mail: cristi@cristek.com.)*

NASA Patents

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Radially Focused Eddy Current Sensor for Detection of Longitudinal Flaws in Metallic Tubes

(U.S. Patent No. 5,942,894)

Inventors: Russell A. Wincheski, John W. Simpson, James P. Fulton, Shridhar C. Nath, Ronald G. Todhunter, and Min Namkung, Langley Research Center

The inspection of longitudinal welds in metallic tubular structures is a major concern in the nuclear power industry, where critical pressure vessels are typically welded together in longitudinal sections. Corrosive environments can speed degradation of these welds. The invention uses a drive coil sized for longitudinal insertion in a metal tube. It is excited by an AC source which induces eddy currents in the tube wall. A pickup coil, sized for lateral insertion in the tube, is spaced apart from the drive coil along the tube's length. This coil has first and second end planes with a longitudinal axis passing through both. The first is positioned to lie adjacent and perpendicular to the wall of the metal tube. An electrical measurement device such as a voltmeter is coupled to the pickup coil to detect flaw-induced voltage across the first end plane of the pickup coil.

Optical-to-Tactile Translator

(U.S. Patent No. 6,055,048)

Inventors: Maurice L. Langevin and Philip I. Moynihan, Jet Propulsion Laboratory

The inability to fully comprehend near-field surroundings poses a threat to the safety of the sight-impaired and can limit their ability to travel freely. There are two traditional ambulatory aids for them, the cane and the guide dog. But a cane, typically moved along the ground's surface as the individual walks, can fail to detect obstacles not on the ground, such as those at head level. A guide dog is an expensive alternative, has many of the same drawbacks as the cane, and relegates the user to a passive rather than an active posture in determining obstacles. The present invention uses an optical sensor to translate a near-field image into a digital signal. A processor receives the signal and converts it to a command that is received by an apparatus providing a physical signal to the user, preferably in the form of a series of pin-type contacts that deliver a tactile interpretation of the near-field image. The tactile transmitter communicates the outline to the user by either reproducing the outline on his skin or producing a pattern that is recognized by the user similar to a Braille system.

Gas Sensing Diode and Method of Manufacturing

(U.S. Patent No. 6,027,954)

Inventor: Gary William Hunter, Glenn Research Center

The invention provides a hydrogen and/or hydrocarbon sensor which can be used at elevated temperatures of 425 degrees C and above for prolonged periods of time for use in catalytic combustion control systems or other applications that depend on the presence of hydrogen or hydrocarbons. It is based on a Schottky diode that includes an alpha silicon carbide substrate, an alpha silicon carbide epilayer, a backside contact, and a palladium chrome contact. The epilayer is an n-type carrier, as is the silicon carbide substrate. The epilayer is grown on a commercially available n-type 3.5-degree off-axis polished c-FACE 6H-SiC substrate. The epilayer surface was etched by a dilute hydrofloric solution, rinsed with deionized water, and blown dry with nitrogen prior to the deposition of the palladium chrome film thereon. Approximately 400 angstroms of the palladium chrome alloy are magnetron-sputter deposited onto the C-face of the epilayer to form a palladium chrome/silicon carbide diode. A backside substrate contact is formed by sputtering aluminum thereon. The palladium chrome contact surface is a catalytic material in the presence of hydrogen, which results in an increased current flow through the diode with a given bias voltage applied to the diode.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. See page 12 for a list of office contacts.

IF YOU CAN THINK IT, WE CAN DO IT.
Emhart is a world leader in the design and supply of innovative fastening and assembly technology. From concept through installation, whether you're manufacturing around the corner or around the globe, Emhart provides cost-effective solutions for assembly applications. Visit us at www.emhart.com
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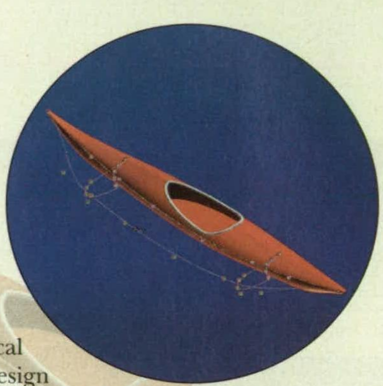
PRODUCT OF THE MONTH



think3, Santa Clara, CA, has released thinkdesign 6.0 3D design software that is designed to increase productivity by incorporating a new graphical user interface that eliminates command-line-driven user interfaces and dialog boxes. Users also have the option of speech-enabled command and control of the system. New 3D functions include Precision Shape Modeling, which allows users to make changes to CAD models very late in the design process and create complex surfaces through intuitive physical definitions of those surfaces. Smart Objects enable users to capture and reuse intelligent design elements, including profiles, solids, and shapes, and to build custom libraries by extracting geometry and design relationships from current or previous projects. Curve, Surface, and Solid Associativity gives designers an integrated, surface-enabled solid modeling environment.

For More Information Circle No. 750

Technology 2000: Innovation on Display

The Technology 2000 show — sponsored by NASA, *NASA Tech Briefs,* and the Air Force Research Laboratory — was held October 29 to November 2 in Bellevue, WA. Located with Tech 2000 were the Small Business Tech Expo and the National SBIR Conference.

The event featured the presentation of the seventh annual SBIR Technology of the Year Awards, which honors companies that have developed novel new technologies through the Small Business Innovation Research (SBIR) program. Awards were presented in four categories — Industrial and Manufacturing, Sensors and Instrumentation, Aviation, and a miscellaneous or Other category — and a Grand Winner was selected from all categories as the top technology of the year.

The winner of the Industrial and Manufacturing category was QRDC of Chaska, MN (www.qrdc.com), for its Energy-Based Smart Skin Structure that protects cargo and sensor arrays from vibration and acoustic disturbance. The technology was funded by the Ballistic Missile Defense Organization (BMDO). The Sensors and Instrumentation category was won by Applied Optoelectronics, Sugar Land, TX (www.ao-inc.com), for the Interband Cascade Laser. The project, funded by BMDO, is a semiconductor laser that enables coherent light emission over a wide wavelength range in the mid-IR.

Triton Systems of Chelmsford, MA (www.tritonsys.com) won the Other category with its NanoTuf™ scratch-resistant coating for prescription and sports eyewear. Funded by the US Navy, the coating provides up to four times the abrasion resistance of conventional coatings. The Aviation category winner was ARNAV Systems of Puyallup, WA (www.arnav.com), for a NASA-funded software that combines GPS navigation with LCD cockpit graphical displays and wireless datalinks to provide an air-to-ground and air-to-air real-time weather reporting system for general aviation.

(Above) **ARNAV's general aviation weather reporting system, winner of the Aviation category, is displayed by (left to right) Michael Durham of NASA's Langley Research Center, Susan Hamner of ARNAV, Jack Sheehan of NASA Langley, and Carl Ray, Executive Director of NASA's SBIR/STTR Programs at NASA Headquarters, Washington, DC.**

(Below) **The SBIR award winners are flanked by Bill Schnirring (far left), Chairman and CEO of Associated Business Publications; and Linda L. Bell (far right), Associate Publisher/Editor, *NASA Tech Briefs*. From left, representatives of the winning companies are: Stefan Murry of Applied Optoelectronics, Daryoush Allaei and Shohreh Pirzad of QRDC, Jeff Bond of BMDO, Tania Mojazza and George Kachen of Triton Systems, and Dan Woodbury of QRDC.**

The Grand Award was presented to Triton Systems for its Army-funded SmartBond™ welding technology. The induction heating technique was designed specifically for joining and heating of plastics and composite structures. SmartBond uses ferromagnetic particles called susceptors that absorb RF radiation. When exposed to RF, the susceptors respond by generating heat. Applications for SmartBond range from aerospace to food packaging and cancer cell treatment.

For more information on the SBIR program and the Technology 2000 series conference and exhibition, visit www.T2Kexpo.com.

Who's Who at NASA

Julie Holland, Director, NASA Commercialization Center, California State Polytechnic University

Julie Holland joined Cal Poly Pomona in September 1998 as Director of the NASA Commercialization Center, charged with implementing the University's business incubation program. She previously worked in the business incubation industry, performing feasibility studies, planning programs, and raising funds.

NASA Tech Briefs: What is the purpose of the NASA Commercialization Center at Cal Poly?

Julie Holland: Essentially, it takes the vast amount of technologies and resources that are produced by NASA in the course of its work and makes it available to the private sector, which then can develop new products that will help all of our lives. It specializes in companies that are using NASA technology to develop new products.

NTB: Does being associated with NASA cause some confusion with potential private-sector business partners?

Holland: One of the things that we often have to explain to an entrepreneur is that we are not an arm or a vehicle to sell their products or services into NASA. In fact, we are outward bound. One of the issues is that not all entrepreneurial companies are technical or have the technical capability to take such technology out of NASA and actually commercialize it, or take a product and get it to market. Part of our role is to first qualify potential entrepreneurs that have that capacity, and then work with the NASA centers to identify technology that makes sense or that fits into the products as conceived by the entrepreneur.

NTB: What are the origins of this project?

Holland: The project started with a five-year strategic plan developed by the University under a new president, Bob Suzuki. One of the six strategies approved was for the University to better leverage its resources into the community. In August 1996, a feasibility study was done to determine whether or not business incubation was a viable project for the University.

This is more than just the NASA Commercialization Center. It is a 52,000 square-foot complex called the Center for Training, Technology, and Incubation. So it is very much part of a master plan to provide a center for technology commercialization that integrates curriculum, student experience, and faculty involvement. Its intention is to be a catalyst for public/private partnerships.

NTB: Now that things are moving forward for the center, is there any potential product or company that stands out as something that's going to have a massive impact?

Holland: Being new, we are just getting started. It takes years for some of these products to develop. We have a core of ten qualified candidates. There are probably four that I can point to that are making the kind of progress that shows they have a strong chance to make it. We are piloting a new program that adapts our commercialization process to the SBIR (Small Business Innovation Research) Phase II candidates. It's a program called NASBO (NASA Alliance for Small Business Opportunities). We're working very closely with NASA Headquarters to look at what the particular needs are for SBIR Phase II winners, and adapt our process so that we can increase the commercialization rate of those technologies. NASA has a fairly good track record that way.

We currently have two SBIR companies: Applied Material Technologies and TAO Systems. The other two that are actively pursuing licenses right now with NASA are Data Institute in the health care area, and Accelerated Performance in the aspect technology field. Both are small, growing companies that are right on the edge of developing new markets in their field.

A full transcript of this interview appears online at www.nasatech.com. Ms. Holland can be reached at jaholland@csupomona.edu.

A "Model" of Interactive Engineering

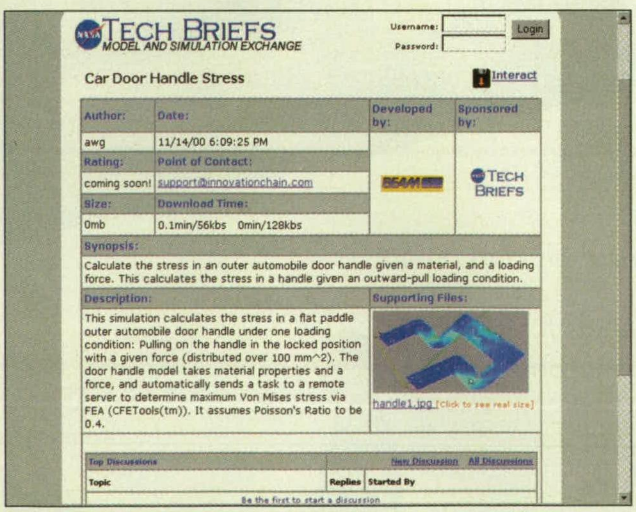
NASA Tech Briefs' new Model and Simulation Exchange allows you to experiment with interactive models of new technologies.

As an official publication of NASA, *NASA Tech Briefs* is the primary vehicle for reporting to industry new, commercially significant technologies developed both at NASA and in the commercial sector. We've seen thousands of fascinating innovations since the publication's launch as single-sheet reports in the 1960s. Of the innovations we've covered, none has offered the power to transform *NASA Tech Briefs* and increase the publication's utility and efficiency to you — until now.

Beginning this month, *NASA Tech Briefs* is launching the Model and Simulation Exchange (http://nasatech.innovationchain.com) as a supplement to the printed material in the briefs and the Technical Support Packages (TSPs). Developed by Innovation Chain of Waltham, MA — with funding from NASA and DARPA — the Model and Simulation Exchange is a specially constructed library for storing, transferring, and simulating models.

NASA Tech Briefs will use the Exchange to enhance published tech briefs by giving them a Web-based, useful, interactive component. Now, in addition to reading about innovations developed by NASA and its industry partners, you can experiment with models of these innovations and evaluate how they operate under the conditions you define. This capability is intended to slash your time-to-decision. Also, if you contribute articles and models to tell potential licensees about your technical developments, you can speed your time-to-revenue.

Several qualities make the models available in the Model and Simulation Exchange unique and valuable to our readers, technology innovators, technology investors, and even advertisers.



Once you've installed the Excel plug-in, you can visit almost any model and interact with it.

Although the universe of simulation-tool suites and modeling styles is nearly limitless, the models in the Exchange use a familiar and nearly ubiquitous user interface: Microsoft Excel. A free, downloadable plug-in to Excel supercharges spreadsheets so they can operate as a Web-enabled control panel, sending and receiving data over the Net, launching simulations on remote servers, and monitoring and reporting on progress. The plug-in functions as a universal data translator, moving simple and complex data types between Excel on your desktop and your own executables or third-party applications running on remote servers.

Herein lies the plug-in's value: its ability to communicate with remote servers. Users of the models published with the tech briefs — such as the "Lean Models" brief on page 52 — will not download the actual models onto their desktops. Instead, users download an Excel control panel and use it to communicate with the models running on a remote server. The remote servers allow model developers to protect their intellectual property — users see only results, not how the model arrived at those results. Perhaps just as importantly, the model runs on the remote server independent of whether the user has the appropriate applications software running locally.

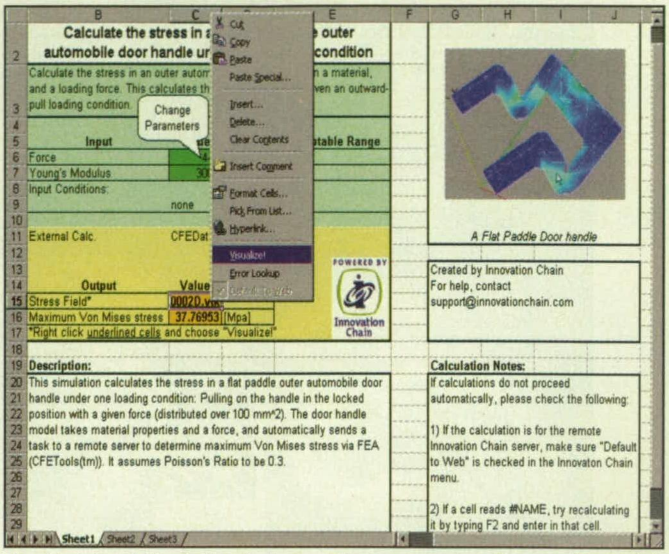
NASA Tech Briefs' intent is to use the technology to supplement the valuable information contained in the tech briefs, as we've done in two briefs in this issue (page 52). Using the URL references in the briefs, we'll point you directly to appropriate models in the Exchange that you can interact with to learn more about specific technologies and products.

The Model and Simulation Exchange offers potential beyond making the tech briefs interactive. An Intranet or Extranet version could facilitate the sharing of proprietary information with widely dispersed colleagues, customers, and suppliers. It also could eliminate redundant development efforts by providing a centralized resource for the collection and distribution of technical information.

(continued on page 24)

(continued from page 22)

NASA Tech Briefs and Innovation Chain invite you to move freely around the Model and Simulation Exchange. You will need to register on the site to download the MS Excel plug-in and interact with the models. When you start the download, we strongly recommend that you "run this program from its current location" rather than taking up disk space by saving the installation program to your local hard disk. Once you've installed the plug-in, you can visit almost any model and interact with it. The plug-in's unique capabilities become obvious as soon as you start interacting with a model.



The Model and Simulation Exchange allows you to experiment with models and evaluate how they operate under specific parameters you set.

The Model and Simulation Exchange will increase in usefulness and value as you and your colleagues contribute models to it. So whether you are an altruistic engineer looking to help your peers save time, or an executive in search of new ways to market your organization's expertise and intellectual property, we encourage you to submit models. Initially, the Exchange's model collection efforts are focused on models that rely on purely algebraic, look-up, or iterative calculations, or models that work with programs you have written.

The technology underpinning the Exchange easily can connect an Excel file to any input/output file-based executables that you've written on the Windows platform. While Innovation Chain's technology does support CAD geometries and other complex data types running on third-party software applications, acquiring licenses and writing the interfaces to all of these applications will take time. To help you get started, templates for a range of model types, as well as directions on how to submit them, are available at http://nasatech.innovationchain.com/howtosubmit.asp.

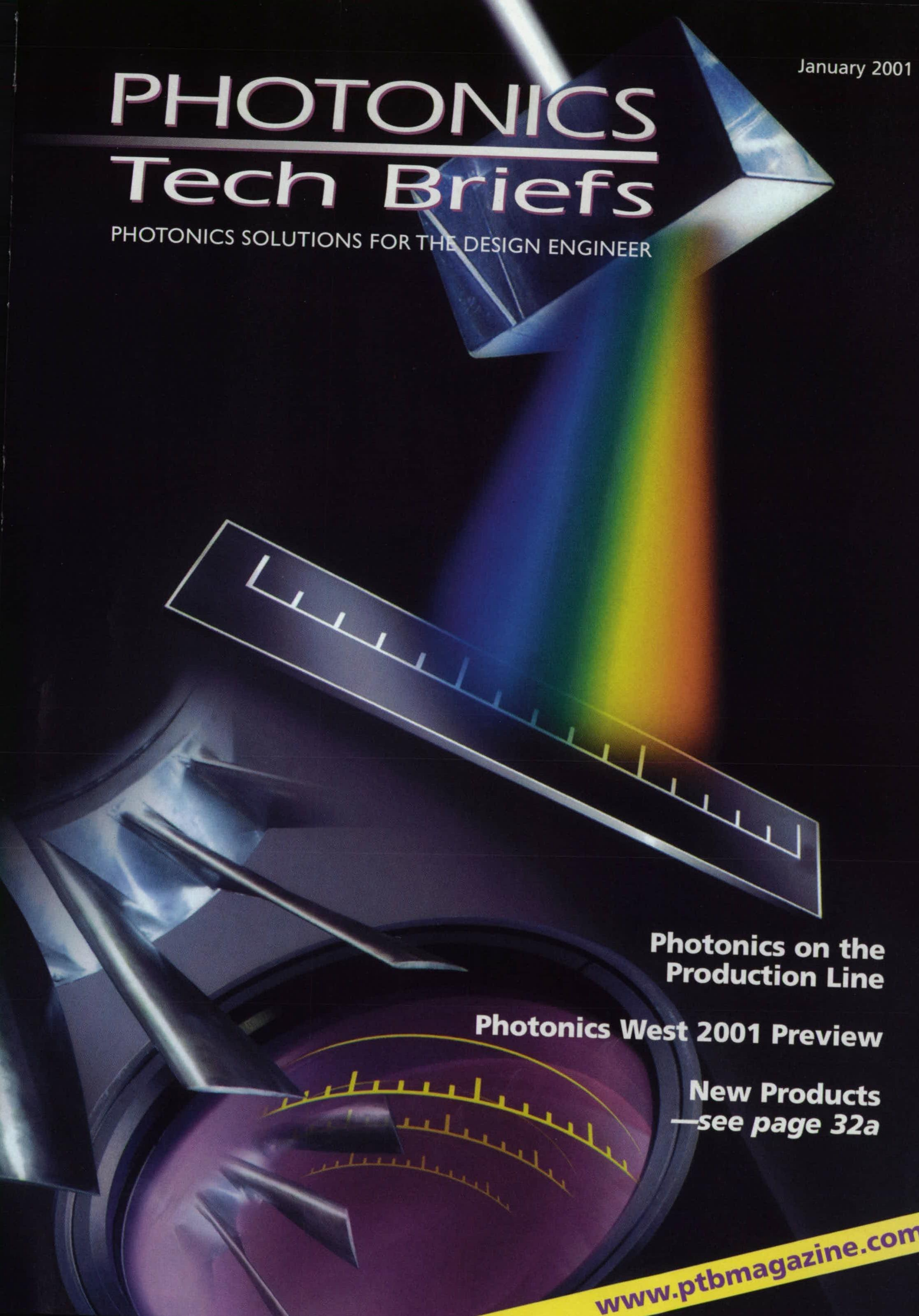
The plug-in and underlying technology require a PC running Windows 98 or higher, or Windows NT 4.0 or higher. In addition, the computer should have available on it Microsoft Excel 97 or higher and Internet Explorer 4.01 or higher.

We strongly encourage you to register, install the plug-in, examine some of the models in this emerging site, and contribute to its growth. Feel free to submit a model in coordination with a tech brief, share a model with friends or colleagues, or use the models whenever you find a link to a model that demands further inspection. And most importantly, let us know what you think.

January 2001

PHOTONICS Tech Briefs

PHOTONICS SOLUTIONS FOR THE DESIGN ENGINEER



Photonics on the Production Line

Photonics West 2001 Preview

New Products
—see page 32a

www.ptbmagazine.com

PHOTONICS Tech Briefs

Supplement to *NASA Tech Briefs'* January 2001 Issue Published by Associated Business Publications

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22a Nonvolatile Holographic Storage in Doubly Doped $LiNbO_3$

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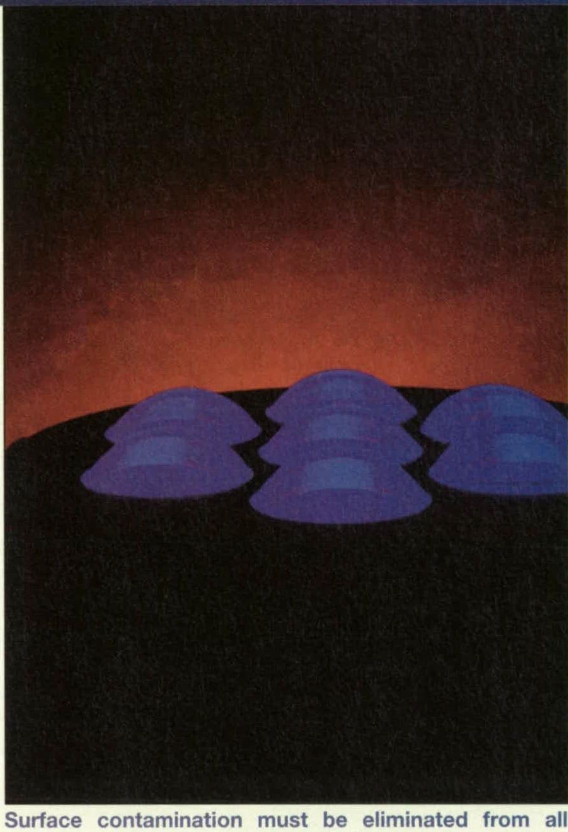
32a New Products

***On the cover:** "Measurement and Detection"-an artist's conception. Photo courtesy of LINOS Photonics, Göttingen, Germany.*

Meeting the Challenge of Coating Contamination

At 157 nanometers, the source of choice for next-generation microlithography, surface contamination presents unique problems.



Surface contamination must be eliminated from all deep-UV optics, or unacceptable transmission losses will occur.

The demand for deep-UV optics is growing rapidly, particularly at the 157-nm fluorine excimer laser wavelength. The most important application is obviously microlithography, where chip manufacturers need shorter wavelengths to produce higher-density memory and processor chips. Indeed, although 193-nm ArF-laser-based systems represent the current state of the art in chip production, the 157-nm laser is now widely regarded as the inevitable source of choice in next-generation microlithography steppers. There are also emerging materials processing applications at 157 nm that rely on this wavelength's high photon energy to ablate "difficult" materials. For example, this is the only readily available laser wavelength that can be used to micromachine teflon.

Unfortunately, surface contamination presents unique problems at 157 nm, posing challenges for optics manufacturers and end users. The reason is that most chemical species demonstrate extremely high absorption at this wavelength. Indeed, the term "vacuum UV" arose because of the need to remove air from the optical path in deep-UV systems. In fact, absorption is so strong at 157 nm that even a *monolayer* of surface contamination (oil, water, or even oxygen) can cause significant losses–up to 15 percent per surface. A microlithography system can contain up to 100 individual optical surfaces, so that a loss of only 2 percent per surface reduces total system transmission by 87 percent.

In addition to the reduced throughput, surface absorption may also lower the lifetime of smaller optics that experience higher fluences. This increases costs to the end user in three ways: the cost of the replacement optic, the cost of down time, and the potential costs caused by introducing more contamination when opening the system for optics replacement.

The end result is that both manufacturers and end users are now faced with eliminating surface contamination at the monolayer level. But fortunately, by following rigorous protocols and practices, this problem can be effectively circumvented without pushing the cost of the optics to an unacceptable level.

Addressing Contamination

The main goals for manufacturers are to produce high-quality (low-transmission-loss) beam-delivery optics with high yields at market-enabling costs. There are really three process stages from the manufacturer's point of view: fabrication, cleaning, and shipping. Surface contamination must be addressed at each stage.

The fluorides used as both substrate and coating materials are chosen for their low losses at 157 nm. Thus, transmission losses are primarily caused by contamination and/or scatter on the surface of the substrate and the outer surface of the coating. The former is the more critical, since there is no way to remove contamination trapped *under* a coating.

Hydrocarbons, oxygen, and moisture are the typical contaminants present when coating optics. At longer wavelengths, some manufacturers rely on storing the substrates under dry nitrogen. This is not sufficient at 157 nm, however, because, while dry nitrogen is moisture-free, it may contain hydrocarbons as well as particulates that could lead to surface-scatter losses. The optics must be stored under ultrapure nitrogen.

It does not take long exposure to the ambient atmosphere to produce a monolayer of surface contamination, so the substrates are always recleaned immediately prior to coating. At these levels, heating the substrate is not sufficient, and manufacturers such as Alpine Research Optics of Boulder, CO, have developed proprietary *in situ* cleaning protocols based on the reactive cleaning method described later in this article. The result is a typical surface transmission of ±99.5 percent per coated surface. The goal is then to maintain this transmission even after shipping to the end user, storage on site, and final installation in the beam-delivery system.

In a microlithography system, the entire beam-delivery path is a closed, clean environment. The system is constructed of materials that outgas very

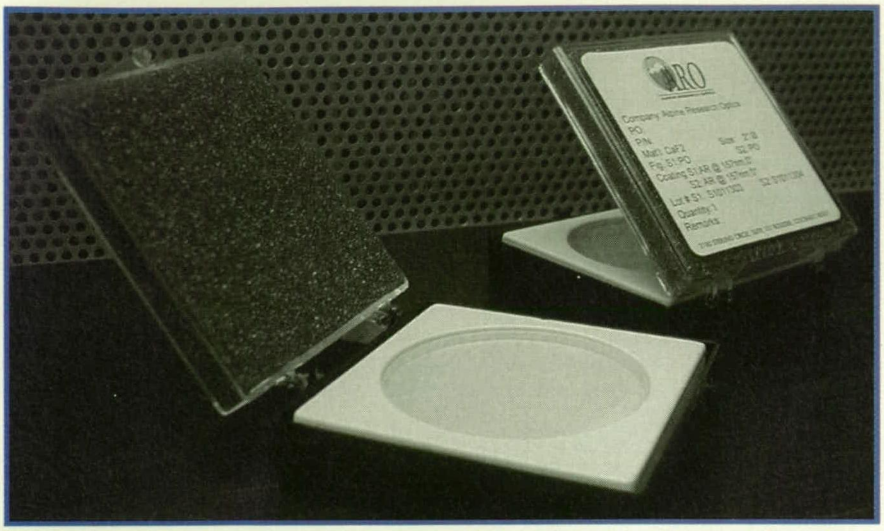


Figure 1. Providing they are properly cleaned before and after shipping, it is perfectly safe to ship 157-nm optics in conventional plastic packaging.

slowly; it is important to note that at this level of contamination, all materials outgas to some degree. To maintain clean optics, the system is continuously flushed with a fresh supply of ultrapure inert gas. Thus, once the optics are in use, they are well protected from contamination. Shipping and storage are another matter, however.

The optics industry is already investigating improved shipping methods for 193-nm optics to avoid contamination during transit. But at 157 nm, the problem is so critical that these are unlikely to offer a complete solution. For instance, the most extreme approach to avoiding contamination during shipping would be to place the optics in a sealed stainless-steel container filled with ultrapure inert gas. The optics would remain unopened until installation. Clearly, with shipping costing more than the optics themselves, this is not a cost-effective approach.

The Correct Protocols

But fortunately, if the correct protocols are followed, small amounts of surface contamination can be completely removed from most 157-nm optics at any time. It therefore makes more sense to ship the optics in conventional plastic packaging (see Figure 1), and to remove any contamination just prior to installation. Alternatively, some end users clean the optics immediately after receipt, and store them in a closed cabinet whose environment mimics the pristine microlithography system.

So what are the correct cleaning methods? The most effective protocol is a two-stage process. The first is to perform a methanol wipe, using high-quality lens tissue and nanograde methanol. The second stage is to perform some type of reactive cleaning. This is carried out in a sealed container continuously flushed with an ultrapure combination of inert gas and oxygen. The component is irradiated with either a deep-UV laser or light from a deep-UV discharge lamp. The reactive combination of energetic photons and oxygen removes most types of surface contamination. (Although ozone probably plays some role in this cleaning, the mechanism is still not fully understood.) The oxidized and vaporized contamination is then flushed away by the gas flow.

It is very important, however, to note that reactive cleaning is not a panacea or one-step process, and must only be used after appropriate precleaning. For example, any silicon containing oils or molecules can be removed by methanol. But if reactive cleaning is used on its own, the silicon material will be transformed into hard deposits of silicon dioxide, which absorb and scatter 157-nm radiation, and which are impossible to remove without damaging the surface.

The effectiveness of this two-stage cleaning method is clearly illustrated in Figure 2. This shows spectrophotometer plots of the deep-UV transmission for the same optic after two types of cleaning: methanol wipe only, and methanol wipe followed by reactive cleaning. Although this two-stage method will remove virtually all types of surface contamination, it should also be used in conjunction with a rigorous program of contamination minimization. In this case, an ounce of prevention is truly worth a pound of cure.

Conclusion

The extremely high absorption of most materials in the deep UV presents many practical barriers to cost-effectively utilizing these wavelengths. The unique benefits offered by deep-UV processing, however, in terms of producing smaller devices and features, has spurred tremendous efforts aimed at overcoming these limitations. The techniques developed for fabricating and handling 157-nm optics clearly illustrate the progress that has already been made.

For more information, contact the author of this article, James Doty, Ph.D., Eastern Regional Sales Manager of Alpine Research Optics, 3180 Sterling Circle, Boulder, CO 80301; (303) 444-3420; fax: (303) 444-1686; e-mail: AROcorp@AROcorp.com; www:arocorp.com. This article is based in part on a presentation by Doty at the Sematech International Symposium on 157-nm Lithography, May 11, 2000, Dana Point, CA.

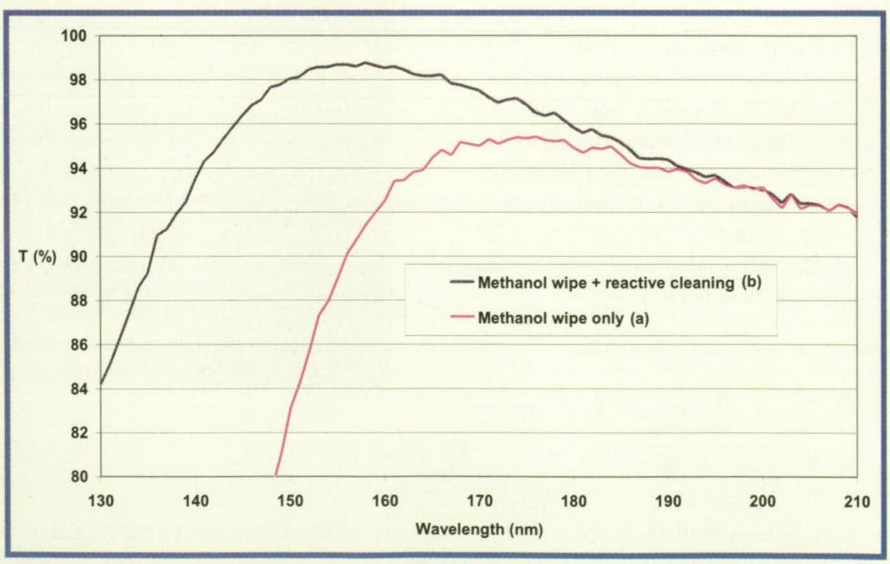
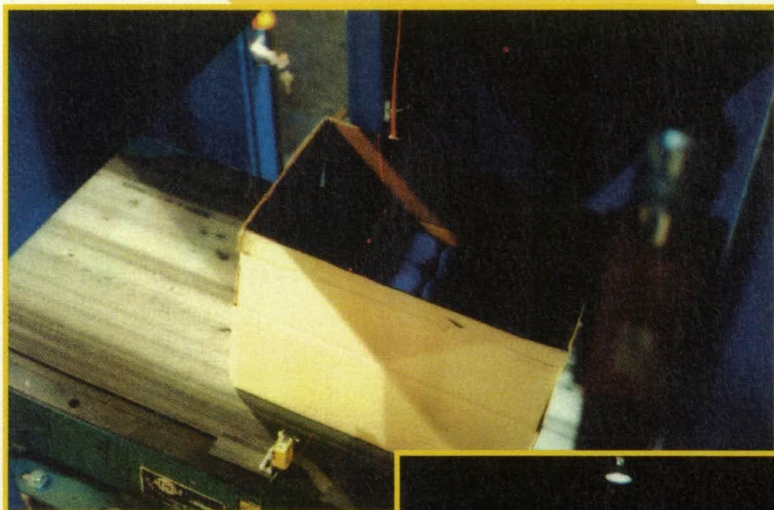


Figure 2. These spectrophotometer traces of the same optic clearly demonstrate the value of reactive cleaning. They show transmission through a 5-mm-thick CaF_2 window, AR/AR both surfaces at 157 nm, normal incidence. (A) was recorded after methanol wiping only; (B) was recorded after methanol wiping followed by reactive cleaning.

BETTER RESULTS ON THE PRODUCTION LINE

A laser measurement scheme yields improved defect detection.



The LMI L1 line scanner scans the top of an aerosol can box for quality control standards.

PDM Technology has developed the quality control inspection system shown at the right, including the custom software designed for it.

PDM Technology Inc., a custom machinery and automation systems integrator, faced the challenge of engineering a manufacturing and versatile test and inspection system to be used in an aerosol can production line by a large consumer products facility in southeast Wisconsin. The system required that it continually adapt to a variety of different product lines, manufacturing variations, and harsh environmental stimuli and yet reduce manual programming and down time.

To meet these requirements, PDM turned to Laser Measurement International (LMI), a noncontact laser measurement manufacturer, for a laser measurement solution. The consumer products company that approached PDM had an existing system in place that utilized a gray-scale vision system to detect defects such as missing caps and cans, inverted caps and cans, folded box flaps, cans on top of a case, or raised cans. When a defect was detected, the system tripped a diverter that conveyed the defective box to a quality control area.

At best, the system detected approximately 99 percent of defects. A problem arose, however, when the packaging-line products differed in cap colors and sizes, which were primarily due to manufacturing variations and not actual defects. The fast vision system was also extremely sensitive to environmental changes and product variables including ambient light levels and cap color. When these slight variations were introduced, the system would malfunction, leading to several hours of down time to make programming changes. Problems incurred when the packaging line itself was changed in size, color, and number of cans per case were increased testing errors from misreadings, extensive manual programming, and excessive down time while setting up.

Enter the L1

To tackle these problems, PDM sought out Laser Measurement International (LMI). PDM had used the


How do we target scanners to all these industries?
BIO-MEDICAL SYSTEMS
• Scanning Microscopy
• DNA Analysis
• Ophthalmology
• OCT
LASER PROJECTION
• Industrial CAD Projection
• Image Projection
• Laser Entertainment
IMAGING AND PRINTING
• Digital Radiography
• Material and PCB Inspection
• High Resolution Printing
• 3D Imaging
SEMICONDUCTOR PROCESSING
• Mask and Wafer Inspection
• Memory Repair
• Laser Trimming
• Micromachining
LASER MATERIAL PROCESSING
• Marking and Engraving
• Welding and Treating
• Via Drilling
With laser precision, of course.

company's sensors successfully in numerous other applications and looked to them to find a rugged device that would meet this project's need for operation under poor light and environmental conditions while having the capability to easily differentiate product variations and actual defects.

After explaining and analyzing the manufacturer's application and PDM's machine-building requirements, LMI specified the L1 line scanner, a 3D noncontact device capable of producing 60 profiles per second. The key to the L1's use in this application is its insensitivity to environmental and manufacturer changes that hindered the older system. This increased accuracy, along with decreasing down time as a result of eliminating the need to manually reprogram each time a different can-box combination was on line. The 3D system is much easier to program and more reliable than 2D systems, according to PDM.

For setup, the operator selects a preprogrammed product class. The custom defect software from PDM automatically calibrates the inspection system by passing three correct cartons under the sensor. The system then calculates all required parameters and begins actual defect testing on the fourth carton.

The L1 sensor is positioned directly above the open cartons being conveyed to a case sealer. If the measurement results are skewed versus the master parameters, the carton is forced onto a diverter, which reduces down time and prevents damage to the case sealer. The system overall helps prevent cases with missing products from reaching the customer, thus reducing customer complaints, additional paperwork, and reshipments.

Getting a Profile

The Class III three-dimensional L1 scanner is designed for high-density profiles in a variety of configurations. Each scan head has a 120-degree field of vision for optimum measurement, and can be used as a standalone unit or in combination with two or more sensors. When two are used, a full 3D image can be measured.

Capable of 60 profiles per second, the scanner has a resolution of 1/16 inch (1.5875 mm) and a depth of view of 16 in.-22 in. (406-559 mm). Built to NEMA-4 (IP 65) standards and enclosed in an aluminum housing, the sensor can operate from 32-105 °F (O-40 °C).

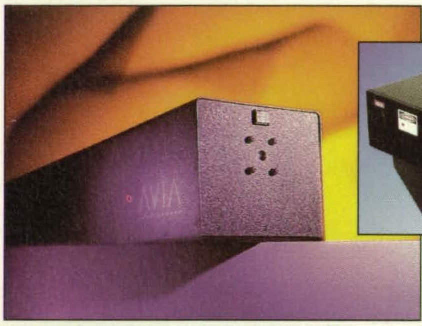
The L1 scanner uses a measurement principle known as optical laser triangulation. A fixed beam of light is projected from the sensor to the surface to be measured. When the light hits the surface, it scatters in all directions. The sensor collects part of this scattered light and maps out the contour of the scanned article, while also generating a profile. The CCD technology allows the profile to be filtered or otherwise processed for accuracy.

As the relative distance between the sensor and measured surface changes, the position of the image on the detector changes proportionally, making it possible to measure the location of the surface accurately and repeatedly.

For more information on the L1 scanner, contact Laser Measurement International Industrial Sensors Division at 21666 Melrose Ave., Southfield, MI 48075, or call (248) 359-2409; fax (248) 355-3283; e-mail sales@LMInt.com; www.LaserSensors.LMInt.com. For more information on this or other turnkey defect detection systems, contact PDM Technology Inc. at (715) 241-0040, or e-mail sales@OPDMtechnology.com.

PHOTONICS WEST 2001

A Photonics Odyssey Showcases the Power of Light



Among the products to be displayed at Photonics West 2001 this month are Coherent's AVIA 4500 and AVIA Ultra lasers (left) and Photonics Industries International's DS series fourth-harmonic UV laser.

If the number 2001 conjures up visions of futuristic science and technology of the kind that enlivened the well-known movie, attendees at SPIE—the International Society of Optical Engineering's Photonics West technical symposia and exhibit at the end of the month won't have to rent the video to catch a glimpse of what's in store for the new millennium. To be held in San Jose's convention center 20-26 January, the event will be built around 2800 research and development papers in 85 conferences showcasing cutting-edge technologies, as well as more than a hundred short courses. The Society expects more than 12,000 attendees from 42 countries, and exhibitors displaying their products in the convention hall look to top 600.

This year's technical program is in four parts: BiOS 2001, the International Biomedical Optics Symposium; LASE 2001, concentrating on High-Power Lasers and Applications; Optoelectronics 2001, focusing on Integrated Optoelectronic Devices; and Electronic Imaging, centering on its Science and Technology. SPIE is continuing its popular "Saturday Night Hot Topics" on 20 January from 7:30 until 9 p.m., with James A. Harrington of Rutgers University moderating a series of discussions of such topics as "Imaging Body Functions and Dysfunctions with NIR Optics," "Cardiovascular Disease," "BioChips," and "New Approach to Optical Imaging of Tumors."

Earlier on Saturday, from 1 p.m. to 5 p.m., and on Sunday from 10:00 a.m. to 4 p.m., three ballrooms in the convention center will display biomedical exhibits. The exhibition halls of the convention center are open from 10:00 a.m. Tuesday, Wednesday, and Thursday to 5:00 pm. on the first two days and 4:00 p.m. on the final day.

The International Biomedical Optics Symposium is organized under several subcategories. "Clinical Treatment and Diagnosis" will present papers on "Laser Welding of Tissue," "Lasers and Other Technologies in Urology," "Lasers and Optical Technology in Otolaryngology," "Innovations in Breast Cancer Diagnosis and Minimally Invasive Therapy," "Thermal Treatment of Tissue: Energy Delivery and Assessment," and several other subjects. "Clinical Technology" will have papers on "Optical Fibers and Sensors for Medical Applications," "Optical Tomography and Spectroscopy of Tissue," "Laser Plasma Generation and Diagnostics, " and other topics. Among the offerings in "Tissue Modification/ Engineering" are "Laser Tissue Interac tion XII: Photochemical, Photothermal, and Photomechanical," "Optical Technologies to Solve Problems in Tissue Engineering," and "Commercial and Biomedical Applications of Ultrafast Lasers." "Cells, Tissues, and Organelles" offers papers on "Functional Imaging and Optical Manipulation of Living Cells and Tissues," "Advanced Techniques in Analytical Cytology V," and "Multiphonon Microscopy in the Biomedical Sciences," among others. "Reporters" will present sessions on "Molecular Probes and Dyes," "Nanoparticles and Nanostructured Surfaces: Novel Reporters with Biological Applications," and "Optical Methods for Tumor Treatment and Detection: Mechanisms." Finally, "Fluids and Molecular Species" will include sessions on "Optical Diagnostics and Sensing of Biological Fluids and Glucose and Cholesterol Monitoring", "Genomics and Proteomics Technologies," "Biomedical Instrumentation Based on Micro- and Nanotechnology," and "Microarrays: Optical Technologies and Informatics."

"LASE 2001" features three programs. "Laser Engineering" considers such topics as "Solid-State Lasers X," "Nonlinear Materials, Devices and Applications II," "Crystal Growth of Lasers and Nonlinear Materials," and "Laser Frequency Stabilization: Standards, Measurements and Applications." Among the papers in "Laser Propagation and Communications" are "Optical Pulse and Beam Propagation III," "Free-Space Laser Communications Technologies XIII," and "The Search For Extraterrestrial Intelligence (SETI) in the Optical Spectrum III." "MicroEngineering/ Manufacturing" will offer "Laser Applications in Microelectronic and Optoelectronic Manufacturing," "Metrology-Based Control for MicroMachining," and other topics.

Optoelectronics Considered

"Optoelectronics 2001" kicks off with a program on "Optoelectronics Materials and Devices," which features sessions on "Organic Photonics Materials and Devices III," "Rare-Earth-Doped Materials and Devices V," "Functional Integration of Opto-Electro-Mechanical Devices and Systems," and more. A second program, "Semiconductor Lasers and Photodetectors," will include "Laser Diodes and LEDs in Industrial, Measurement, Imaging, and Sensors Applications III," "Vertical-Cavity Surface-Emitting Lasers V," "In-Plane Semiconductor Lasers V," and "Photodetector Materials and Devices VI," among others. "Hybrid and Monolithic OEICs," the final program,

will consider "WDM and Photonic Switching Devices for Network Applications II," "Optoelectronic Integrated Circuits V," "Optoelectronic Interconnects VIII," and "Diffractive and Holographic Technologies for Integrated Photonic Systems," among other topics.

Last but not least are seven programs brought together under the umbrella of "Electronic Imaging 2001." "2D Displays" will take in "Projection Displays VII," "Thin-Film Transistor Flat Panel Display Technology and Applications," and "Display Metrology II." "3D Capture and Display" will consider "Practical Holography XV," "Stereoscopic Displays and Applications XII," "The Engineering Reality of Virtual Reality," "Three-Dimensional Image Capture and Applications IV," and other topics. "Electronic Imaging Systems and Image Processing Methods" will present papers on "Machine Vision Applications in Industrial Inspection IX," "Real-Time Imaging V," "Nonlinear Image Processing and Pattern Analysis XII," and "Applications of Artificial Neural Networks in Image Processing VI," among others. "Multimedia Processing and Applications" will offer sessions on "Internet Imaging II," "Security and Watermarking of Multimedia Contents III," and ""Storage and Retrieval for Media Databases," among others. The remaining three programs—"Document Imaging, Sensors, and Camera Systems," "Image Sequence and Data Analysis," and "Visual Communications and Image Processing"—contain sessions that range widely through the fields of sensors, cameras, digital photography, and document recognition.

Product demonstrations and activities take place in the exhibit-floor "town squares" throughout the three days of the exhibit. Subject matter ranges widely: "Subcompact High-Speed Laser" (Thermo Laser Science), "Recent Innovations in 3D Surface Microscopy" (Veeco Metrology Group), "High-Aspect-Ratio Microstructures and Radiation Detectors" (Lawrence Berkeley National Lab), "266-nm UV Diode-Pumped Solid-State Laser" (Photonics Industries International), "IEEE 1394 and Digital Cameras" (Hamamatsu Corp.), "Asphere Manufacturing for the New Millennium" (QED Technologies), "Photonics CAD in the Fast Lane" (Photon Design), "Just Released-ASAP 7.0 Optical Modeling Software" (Breault Research Organization), "Diamond Machining/Grinding Systems for Telecommunications, Infrared, and Other Materials" (Precitech), and so forth.

Among other special events is a series of talks by academic and business notables. On Monday, 22 January at 4 p.m., Kenichi Iga of the Tokyo Institute of Technology will address "The Semiconductor Laser in the 21st Century;" at the same time Prof. Raymond Y. Chiao of the University of California at Berkeley will talk about "Apparently Faster-than-Light Effects and Negative Group Delays in Optics and Electronics, and their Applications." On Tuesday at 8:30 a.m., Yrjo Neuvo, executive vice president for technology of Nokia Mobile Phones, will tell how "Wireless Salutes Multimedia." At the same time the next day, Larry J. Hornbeck of Texas Instruments will delve into "Digital Cinema: More than a Century after Lumiere." On the 25th, David G. Stork of the Ricoh Research Center and Stanford University will address "The HAL 9000 Computer and the Vision of '2001: A Space Odyssey.'"

Symposium registration fees include admission to all conference sessions, one proceedings volume, one abstract book, plenaries, panels, poster sessions, receptions, coffee breaks, and exhibits admission. For more information, or to register, contact SPIE at (360) 676-3290; fax: (360) 647-1445; e-mail: pw@spie.org; web: www.spie.org/ info/pw.

PHOTONICS *file*

Recent photonics briefs published in NASA Tech Briefs

Many photonics-related briefs from NASA's field center laboratories appear in *NASA Tech Briefs* rather than in the *Photonics Tech Briefs* supplement. Listed here are some from issues of *NASA Tech Briefs* just past, edited for brevity and indexed with reference to original publication and the availability of a Technical Support Package on *Photonics Tech Briefs'* web site.

NASA Tech Briefs September 2000, page 73

Writing Circuit Patterns by Use of Scanning UV Lasers *(NPO-20495)*

Scanning ultraviolet lasers would be used to expose ultraviolet-sensitive photoresists to form patterns of conductors for electronic circuits, a team at NASA's Jet Propulsion Laboratory proposes. Heretofore, such patterns have been formed by exposing photoresists to collimated ultraviolet or visible light through contact or proximity photomasks. The use of scanning lasers would make it unnecessary to make or use masks, and it would be amenable to rapid fabrication of prototype circuits. In forming a given circuit pattern, the scanning of the laser would be controlled by use of the same plotting data, generated by computer-aided-design software, that would otherwise have been used to plot the photomask for the pattern.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Manufacturing/Fabrication category.*

NASA Tech Briefs October 2000, page 40

Tunable Terahertz Source Based on Near-Infrared Diode Lasers *(NPO-20636)*

A heterodyne photonic apparatus built around three continuous-wave, near-infrared diode lasers generates electromagnetic radiation at an adjustable, precisely defined frequency in the terahertz range. The apparatus, developed at NASA's Jet Propulsion Laboratory, could serve as a prototype of tunable far-infrared sources and heterodyne up- and down-converters for fiber optic communication systems and for testing infrared systems in general. The overall photonic system can be characterized as a photomixer pumped by a photonic master-oscillator/power-amplifier (MOPA) subsystem. Typically, the system is operated at a power-amplifier output power level of 30 mW, yielding a terahertz output power of about 0.1 microwatt. The frequencies of lasers 1 and 2 are controlled by locking them to different longitudinal modes of a reference cavity in the form of an ultralow-expansion Fabry-Perot etalon. The difference frequency between lasers 1 and 2 is discretely selectable in increments equal to the free spectral range (FSR) of the reference cavity. Laser 3 is heterodyne phase-locked to laser 2, offset in frequency by an amount established by a tunable microwave synthesizer that operates in the frequency range of 3 to 6 GHz. The difference frequency between lasers 1 and 3—the final output in the terahertz range—is the sum of the microwave offset frequency and an integer multiple of the FSR of the reference cavity.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Electronic Components and Systems category.*

NASA Tech Briefs October 2000, page 44

Room-Temperature Infrared Instrument Detects Trace Gases *(MSC-22864)*

A compact, portable, mid-infrared, laser-based instrument that operates at room temperature has been developed at Johnson Space Center for use in detecting trace concentrations of CO or any of several other gases in air. The instrument utilizes infrared absorption spectroscopy in a sample cell, which either holds an air sample or is exposed to an airflow. The laser beam that interrogates the cell is formed by difference-frequency generation (DFG) in a bulk nonlinear optical medium excited by two laser beams. The pump and signal beams are combined by a dichroic beam splitter and focused by a lens, at nearly normal incidence, into a nonlinear optical medium, a periodically poled lithium niobate. Difference-frequency mixing produces an idler beam, the one that is used to probe the sample cell. An off-axis paraboloid mirror collects the idler beam at the output of the cell, and focuses it onto an HgCdTe photodetector. In the output of the photodetector, absorption signals take the form of amplitude modulation. The spectroscopic information, collected by a computer, consists of the photodetector output voltage as a function of the laser-frequency-control voltage.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Test and Measurement category.*

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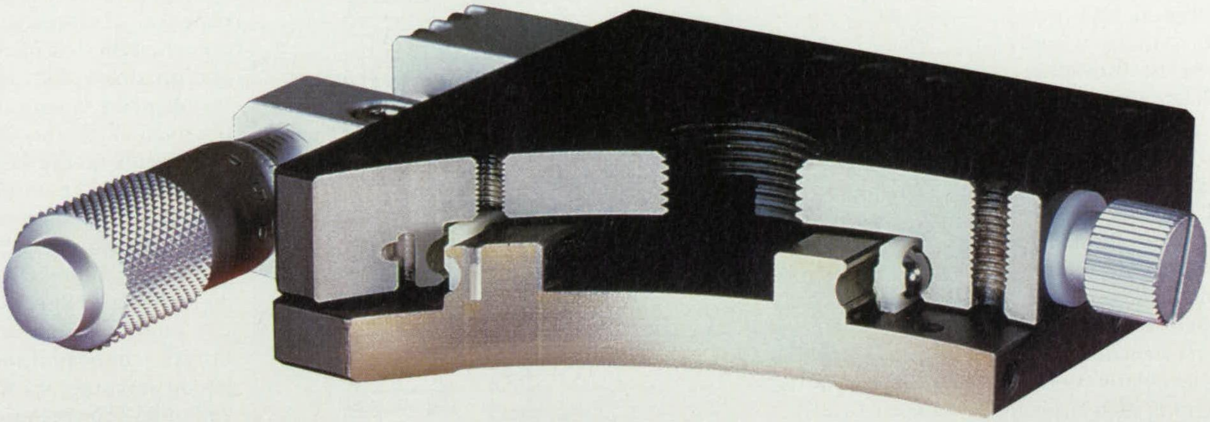

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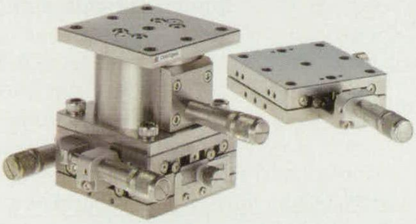

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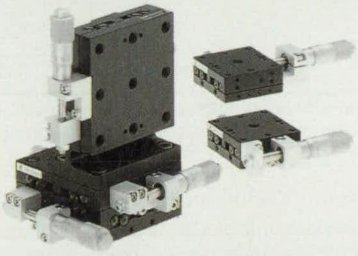

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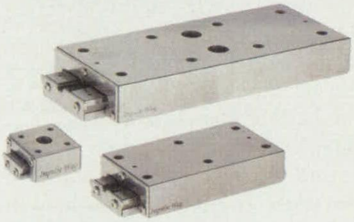

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Using Laser Rangefinders To Align Two Structures

Distance measurements are updated every few seconds.

John F. Kennedy Space Center, Florida

An optoelectronic system provides information on the relative position and orientation of two structures that are required to be brought together slowly and gently in a prescribed alignment. In the original intended application, the two structures will be the X-33 launch vehicle and a launch mount. With modifications, the system could likely be used for aligning other paired structures; it may be particularly valuable for aligning such large and/or heavy structures as prefabricated sections of bridges, for docking of ships, and possibly even for coupling of railroad cars.

In the original intended application, the X-33 will be backed horizontally out of its processing bay directly onto the launch mount (see Figure 1). The X-33 and the launch mount will then be tilted, as a unit, until the X-33 faces upward.

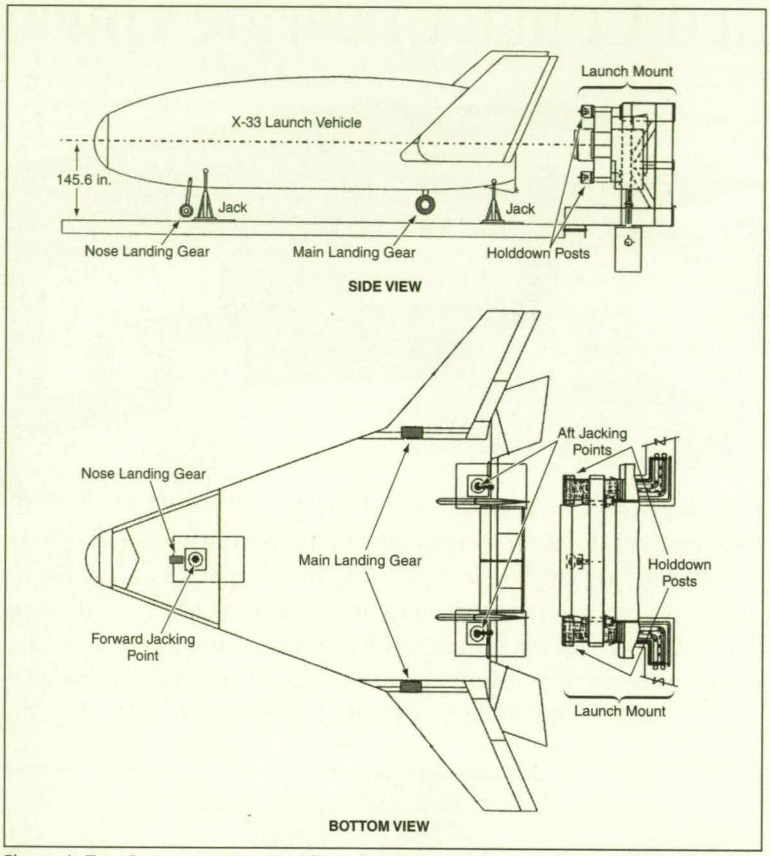

Figure 1. **Two Structures Must Be Aligned** as they approach each other. In this case, the X-33 is backed onto the launch mount and must be aligned with the launch mount at the moment of contact.

The X-33 will make contact with the launch mount at four holddown posts. To prevent damage to the X-33, the angular misalignment between the two structures and the lateral offsets between the nominal contact points on the two structures must be kept within tolerances as the structures are brought together. This means that adjustments will be necessary. The X-33 will be mounted on three air-bearing jacks that will enable the necessary adjustments in all six degrees of freedom: up/down, right/left, backward/forward, roll, pitch, and yaw.

The information provided by the present optoelectronic system will be used to guide the adjustments as the two structures approach. The system (see Figure 2) includes four commercial laser rangefinders fixed to the launch mount. Each laser rangefinder is aimed through one of the holddown posts at a bull's-eye alignment target on the X-33. Each rangefinder measures the distance between its target and the contact face on the end of its holddown post. These measurements can be used to calculate pitch, yaw, and front-to-back distance. Information on roll, right/left offset, and up/down offset can be obtained visually by observation of the displacements of the laser spots from the centers of their respective targets.

The rangefinders are controlled and read out digitally via built-in RS-232 interfaces that are, in turn, connected to a laptop computer via RS-232-to-RS-485 protocol converters. The RS-485 protocol includes an addressability feature that makes it possible to connect the rangefinders in a daisy-chain arrangement in which the computer can communicate with any or all rangefinders through a single port. Software that controls the system and displays the rangefinder readings is written in LabView. The distances are displayed to the nearest tenth of an inch (≈2.5 mm); they are updated at intervals of about 4 to 5 seconds for a computer containing a Pentium (or equivalent) processor, or about 7 to 8 seconds for a computer containing a '486 (or equivalent) processor. The rangefinder readings can be zeroed by pressing a zero button on the computer screen while holding flat objects against the ends of the holddown posts.

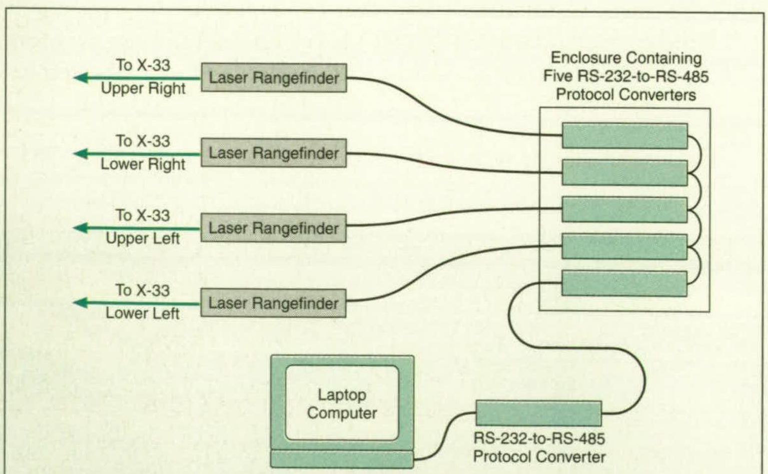

Figure 2. **Four Laser Rangefinders** controlled by a laptop computer measure the distances from the holddown posts to targets at contact points on the X-33.

This work was done by Donald E. Burris and Paul A. Schwindt of **Kennedy Space Center** *and Geoffrey K. Rowe, Robert C. Youngquist, William D. Haskell, and Robert B. Cox of Dynacs Engineering Co., Inc. KSC-12040*

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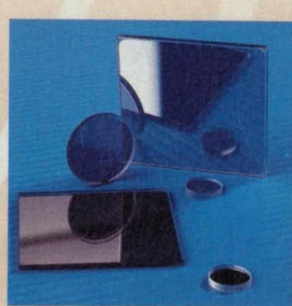

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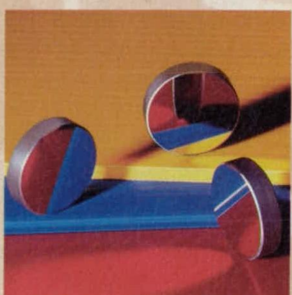

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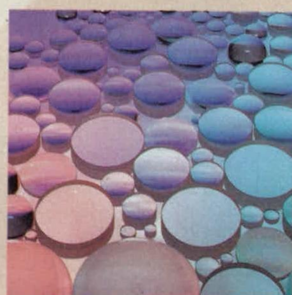

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Mirror Structures Made of Pyrolytic Graphite

Notable characteristics include stiffness, low mass density, and low thermal distortion.

Marshall Space Flight Center, Alabama

Experiments have demonstrated the feasibility of making mirror structures that comprise a thin face plate of chemical-vapor-deposited (CVD) pyrolytic graphite (PG) integrated with a thicker backing plate of CVD PG open-cell foam. The backing plate serves as a stiff structural support for the face plate, on which a precise mirror optical surface can then be formed. Lightweight, highly precise mirrors for telescopes (including telescopes in outer space) and for aiming laser beams could be fabricated following this approach.

Considered on the basis of cost and performance, CVD PG may be the most effective available structural material for precise, lightweight mirrors. CVD PG is produced by thermal decomposition of natural gas, which is available in abundance at low cost. PG is a highly ordered (with respect to molecular structure), high-stiffness phase of carbon that has a very low mass density (2.1 g/cm^3), a very low coefficient of thermal expansion ($<10^{-6}$ K^{-1}), and an in-molecular-plane thermal conductivity of 372 $W/(m{\cdot}K)$ (rivaling that of copper). In addition, PG can be polished to high optical quality (a root-mean-square surface roughness <10 Å). The hardness of PG can be tailored to alter the degree of polishability and the cost of polishing.

What has made the fabrication of unitary, all-PG mirror structures possible is the development of a CVD process in which a fully dense PG face plate is deposited directly on a CVD PG foam support. The great advantage afforded by this process is that the structure produced contains no dissimilar materials, so that thermal distortions associated with differential thermal expansion can be expected to be minimal. The process is as applicable to complex, curved mirrors as it is to flat ones. The areal mass densities of CVD PG mirror structures are expected to be <10 kg/m^2, and may even range as low as 5 kg/m^2.

In flexure, compression, and thermal-expansion tests, CVD PG foam has been found to exhibit the high stiffness and low thermal expansion required of a lightweight structural-support material for mirrors. The rigidity of CVD PG was further demonstrated during grinding and polishing of mirrors. While the fabrication processes have not yet been optimized, it has been established that lightweight, stiff CVD PG mirror structures can be formed and mirror surfaces can be polished on their face plates, all at relatively low cost.

This work was done by Brian E. Williams and Shawn R. McNeal of Ultramet for **Marshall Space Flight Center**. *The company currently has a patent application pending. For further information, please contact the company at* ***mail@ultramet.com*** *or (881) 899-0236.*

MFS-31483

Optical Surfaces Based on Arrays of Microscopic Pillars

Optical properties of some moth-eye structures would be exploited.

NASA's Jet Propulsion Laboratory, Pasadena, California

Surfaces would be textured with dense arrays of pillars characterized by micron and submicron dimensions, according to a proposal, in order to impart desired optical properties to the surfaces. In an important class of potential applications, suitably shaped and dimensioned microscopic pillars would be etched into the surfaces of lenses or photodetectors to suppress reflections and thereby also increase the proportion of light utilized. In another important class of potential applications, surfaces would be so textured in order to obtain both absorption and low reradiation in a wavelength range of interest.

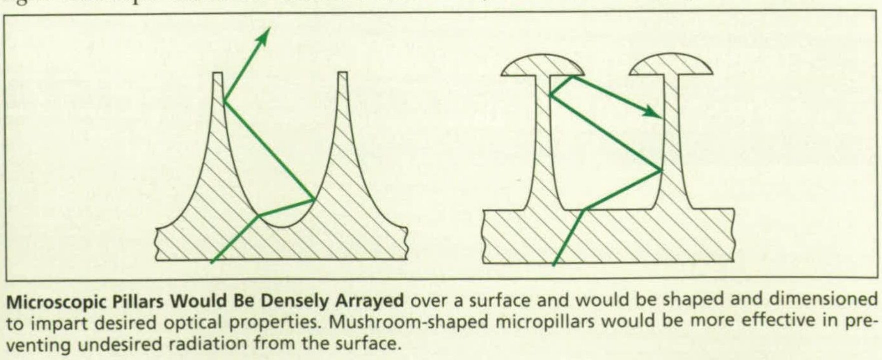
This proposal is an extension of the one reported in "Optical Filters Based on Dense Arrays of Microscopic Pillars" (NPO-20448), *NASA Tech Briefs*, Vol. 24, No. 5 (May 2000), page 27a. To recapitulate: It has been observed that the eyes of moths reflect almost no light. It has been conjectured that the low-reflection property of moth eyes is attributable to dense arrays of microscopic pillars that exhibit little or no diffraction or scattering because (1) the dimensions and pitches of the pillars are smaller than the shortest wavelength of incident light in the wavelength range of interest and (2) a dense array of pillars provides a gradual transition in the effective index of refraction from open space to a bulk solid material, so that an abrupt index change, which would generate reflections, is not present.

Going beyond the previously reported proposal, the present one calls for exploitation of the fact that a dense array of micropillars at a given temperature can absorb electromagnetic radiation predominantly in one wavelength range while reradiating predominantly in another (usually longer) wavelength range. For example, a baffle in a visible-light telescope could be textured with pillars shaped and dimensioned to maximize absorption of visible light. At a typical operating temperature, the black-body radiation from such a baffle would occur predominantly at wavelengths in the infrared region — out of the pass band of the telescope.

For another example, germanium micropillars with a pitch of about 1.5 μm would absorb infrared light at wavelengths in the vicinity of 1.5 μm and would reradiate predominantly at wavelengths >6 μm — the wavelength range that contains the peaks of black-body spectra for temperatures in the cryogenic range. Thus, the micropillar-textured germanium surface would behave somewhat as a radiative diode. It could be used, for example, to absorb solar infrared radiation for heating during the day. It would also help retain the heat during the night because it would reradiate only slightly, even though it would likely be warm in relation to its environment.

Surfaces textured with pyramidal, conical, and rectangular parallelepiped micropillars have been fabricated by use of holography. However, in order to resemble true moth-eye structures more closely and thereby afford more of the benefits of moth-eye structures, micropillars would have to be shaped more like mushrooms (see figure). It would be necessary to use x-ray lithography to fabricate arrays of mushroom-shaped micropillars. The large depth of focus achievable in x-ray lithography would make it possible to generate arrays of precise micropillars on curved surfaces, including concave and convex lens surfaces.

This work was done by Frank Hartley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20565*



Microscopic Pillars Would Be Densely Arrayed over a surface and would be shaped and dimensioned to impart desired optical properties. Mushroom-shaped micropillars would be more effective in preventing undesired radiation from the surface.

Tailoring Cores of Optical Fibers by a Sol-Gel Method

Core dopants can be tailored for specific photonic applications.

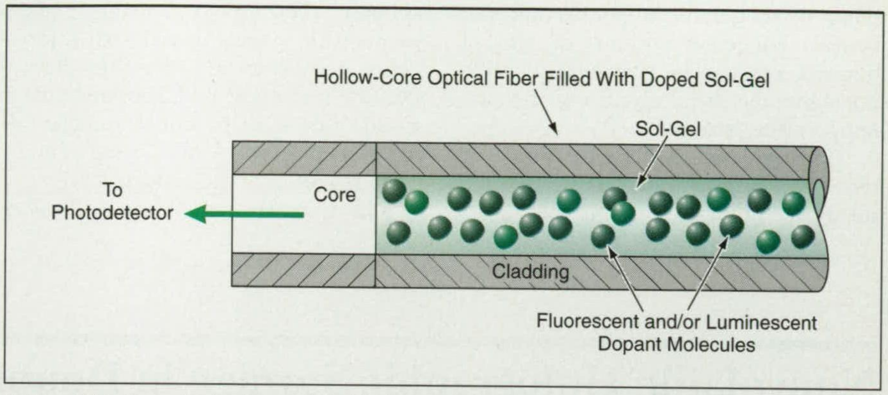
Goddard Space Flight Center, Greenbelt, Maryland

A method of tailoring the cores of optical fibers to obtain optical properties needed for specific photonic applications exploits the sol-gel process. The method is expected to open new avenues of development of fiber-optic sensors for measuring strain, temperature, intensity of ionizing radiation, concentrations of chemicals, and numerous other quantities.

Heretofore, the optically active dopants that constitute the transducer materials of fiber-optic sensors have generally been incorporated into films deposited on the exterior surfaces of optical fibers. In some cases that are particularly relevant to the present development, the exterior films have been doped sol-gels. The operation of such a sensor depends on evanescent-wave coupling of light between core of the fiber and the dopant(s) in the coating film. However, the inherent weakness and large optical loss of evanescent-wave coupling are obstacles to the attainment of adequate sensor response.

If the dopant(s) could be incorporated into the core, the optical coupling would be much stronger and the sensory light could propagate to the detection equipment with very little loss. In addition, given the limit of solubility of the dopants in the sol-gel reaction mixture and the wave-propagation geometry, the optically effective quantity of dopant that could be contained in the bulk of the core would be much greater than the optically effective quantity of dopant that can be contained in an exterior sol-gel sensory film. The net effect of incorporating the dopant into the core would be to make the sensor much more sensitive. The present method exploits this effect.

A fiber-optic sensor fabricated by this method offers an additional advantage (beyond direct vs. evanescent-wave coupling) over a comparable prior-art sensor that comprises an optical fiber coated with a doped sol-gel film. This advantage arises in connection with the fact that to prevent thermal degradation of dopants in the prior art, it is necessary to deposit the sol-gel film first, then diffuse the dopants into the pores of the film. As a result, there is a tendency for the dopants to leach out of the pores of the sol-gel film in some sensor operating environments. In the present method, there is little or no tendency for the dopants to leach out because the dopants are incorporated deep within the sol-gel core, which, in turn, is protected from the environment by the cladding layer of the fiber.



A **Monolithic Core** of sol-gel material with dopant molecules in its pores is formed in an initially hollow optical fiber.

In the present method, the dopants are dissolved and incorporated as ingredients in a sol-gel reaction mixture, which is injected into an initially hollow optical fiber. The sol-gel is then polymerized, forming a monolithic solid core that comprises a porous sol-gel with the dopants occupying its pores (see figure).

One main obstacle that had to be overcome in the development of the present method was the tendency of sol-gels to shrink and crack during polymerization. In fiber-optic sensors, cracks cannot be tolerated because they cause large optical losses. Moreover, the extreme temperatures and pressures

often used for processing sol gels will cause fatigue and damage to optical fibers and preclude the use of many biochemical dopants. The success of the present method stems from the development of sol-gel formulations that can contain adequate amounts of sensory dopants and can be polymerized while managing the shrinkage in a near-room-temperature process.

The process for fabricating the tetraethyl orthosilicate (TEOS) based sol gels employs a number of agents to reduce the process problems inherent in the condensation-polymerization process. A variety of configurations of sensors is being evaluated, including sensors utilizing intrinsic and extrinsic sol-gels. Fluorescent sensing experiments with sol-gels doped with fluorescence derivatives and calcofluor derivatives are underway. Both substances have a wide variety of potential applications in biochemistry and monitoring of metabolic reactions at the cellular level.

This work was done by Harry C. Shaw and Michele V. Manuel of **Goddard Space Flight Center** *and Melanie N. Ott of Sigma Research and Engineering. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13913.

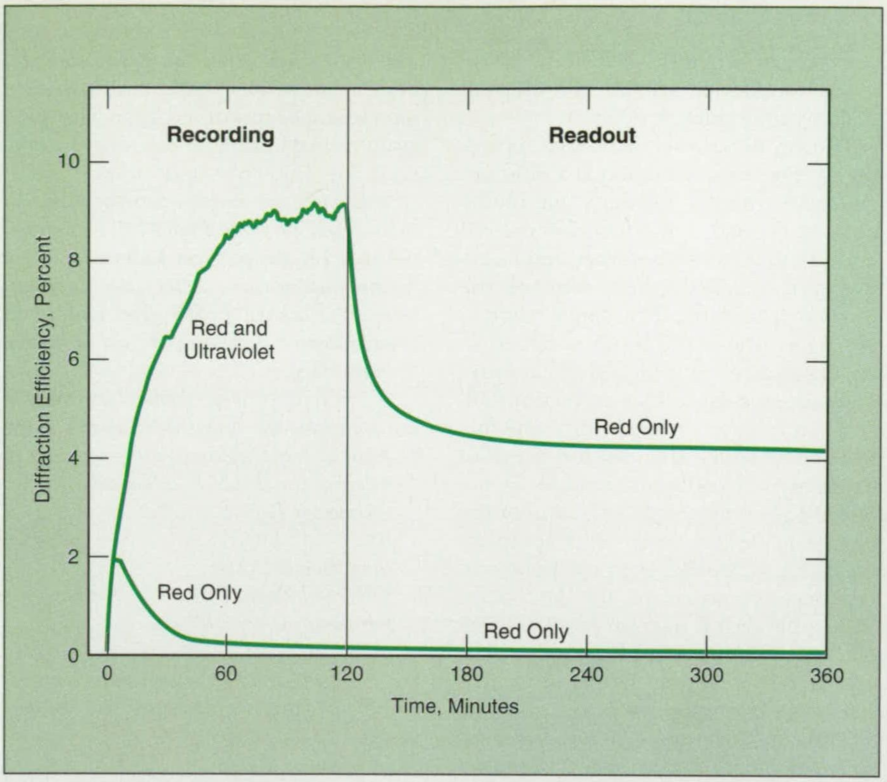
Nonvolatile Holographic Storage in Doubly Doped $LiNbO_3$

Nonvolatile holograms can be written with red light in the presence of ultraviolet.

NASA's Jet Propulsion Laboratory, Pasadena, California

Recent research has demonstrated the feasibility of an all-optical method of recording and readout of holograms in photorefractive crystals, with capabilities for both nonvolatile storage and erasure on demand. Heretofore, volatility has been the primary remaining obstacle to the full implementation of holography with these capabilities: In a typical previously developed holographic system of this type, the readout process erases the stored information and amplifies scattered light.

The present method involves a crystal of the photorefractive material lithium niobate doped with iron and manganese, which are present in the form of Fe^{2+} and Fe^{3+} ions and Mn^{2+} and Mn^{3+} ions, respectively. These ions act as deep electron traps, with energy levels between the conduction and valence bands of $LiNbO_3$. The Mn traps are deeper than the Fe traps; this feature renders the doped $LiNbO_3$ crystal pho-



Diffraction Efficiency of a Holographic Grating in a crystal of $LiNbO_3$ doped with Fe and Mn was measured during recording and readout.

tochromic in addition to photorefractive. The origin and nature of this photochromism are as follows:

Initially, the electrons tend to be in the deeper Mn traps and consequently the crystal is transparent at photon energies for excitation from the $Fe^{2+/3+}$ level to the conduction band (these photon energies correspond to wavelengths centered at 477 nm). If the crystal is illuminated with light at higher photon energies (e.g., ultraviolet light) that can ionize the deeper Mn traps, then the Fe traps become populated and the crystal becomes absorptive over a wide range of visible wavelengths. One can make the crystal revert to transparency by illuminating it with visible light that transfers the electrons from the Fe traps back to the Mn traps. This photochromism is exploited in the present method.

In experiments, a crystal of $LiNbO_3$ doped with Fe and Mn was illuminated by various combinations of (1) unpolarized ultraviolet light (wavelength of 365 nm) from a mercury lamp and (2) interfering beams generated by splitting the 633-nm-wavelength (red) beam from a He/Ne laser. From time to time, one of the He/Ne beams was blocked and the efficiency of diffraction of the remaining beam from the holographic grating formed by the interfering beams was measured.

The figure presents some of the results of the experiments and helps to illustrate the reasoning that led to the conception of the present method. The lower curve shows the evolution of the diffraction efficiency when a holographic grating was recorded with the He/Ne beams only, following a two-hour preexposure to ultraviolet light. The diffraction efficiency increased rapidly, reached a maximum, and thereafter decreased almost to zero. This curve is interpreted as follows:

1. The ultraviolet preexposure excited electrons from the Mn traps and populated the Fe traps homogeneously.
2. Because the Fe^{2+} ions could absorb red light, the interfering He/Ne laser beams recorded a hologram: interference maxima yielded large photovoltaic currents, which built up space-charge fields, which, in turn, induced changes in the index of refraction.
3. However the Fe^{2+} sites became bleached in the high-intensity regions and hence the currents there decreased. Ultimately, the darker regions also became bleached and all electrons became trapped by the Mn^{3+} ions.
4. The final Mn^{2+} concentration was almost completely spatially homogeneous because (a) the experiment began with a homogeneous concentration of Fe^{2+} and (b) each excited charge carrier was moved in the same direction by approximately the same distance before it became retrapped by Mn^{3+} ions, so that (c) the final space-charge field was very small. Thus, the

exposure schedule described above was found not suitable for efficient nonvolatile storage.

The key to nonvolatile storage according to the present method is a different exposure schedule in which one illuminates the crystal with ultraviolet and red light simultaneously and waits until saturation is reached, then switches the ultraviolet light off. The upper curve in the figure shows the result obtained in an experiment in which this exposure schedule was used. The diffraction efficiency during recording by this schedule was much larger than in the previous experiment. In addition, readout by use of red light erased only a fraction of the hologram because even after complete bleaching of the Fe^{2+} sites, the hologram remained recorded in the Mn traps. Thus, the crystal was rendered insensitive to red light and readout by red light was thereby rendered non-erasing; that is, storage became nonvolatile.

Thus, in the present method, a nonvolatile hologram is recorded by exposing the crystal simultaneously to incoherent ultraviolet light and coherent interfering beams of red light. The hologram can be erased by exposing the crystal to the ultraviolet light only.

This work was done by Karsten Buse, Ali Adibi, and Demetri Psaltis of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at*** ***www.nasatech.com*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20379, volume and number of this NASA Tech Briefs *issue, and the page number.*

Compact, Low-Power, Low-Voltage Laser Ignition System

A glow plug is heated by a laser beam delivered via an optical fiber.

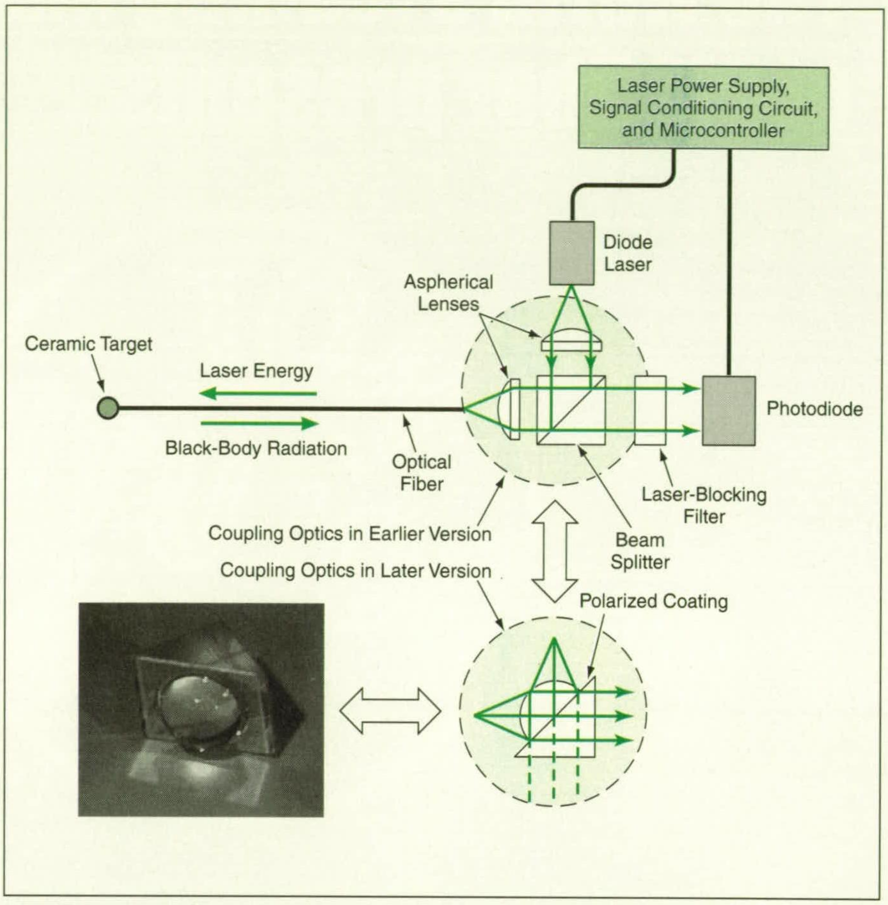
Lyndon B. Johnson Space Center, Houston, Texas

A prototype laser ignition system has been developed for use in a hydrogen/oxygen-burning spacecraft thruster. The system could readily be adapted to terrestrial applications in which spark, catalytic, or pyrotechnic igniters are now used.

The operations of spark igniters and some previously investigated pulsed laser igniters involve high-voltage transients that give rise to electromagnetic interference. In addition, the previously investigated laser igniters project their beams into combustion chambers via windows, which are susceptible to obscuration by deposition of byproducts of combustion. Moreover, neither spark igniters nor the previously investigated laser igniters are designed to test themselves. In contrast, the present laser ignition system operates at low voltage, does not depend on a transparent window, and incorporates self-testing features.

In the present laser ignition system, the ignition device is basically an optically heated glow plug: The output of a diode laser is delivered, via an optical fiber, to a ceramic target in a combustion chamber (see figure). The laser beam heats the target above the hydrogen/oxygen autoignition temperature. Some of the black-body radiation from the heated target travels back along the optical fiber, is separated from the laser beam by a beam splitter and a laser-blocking filter, and impinges on a photodiode. The output of the photodiode is an indication of the temperature of the target; as such, it provides complete verification of the functionality of the entire optical train from the laser to the target. This self-testing feature can be used alone or in combination for verification of combustion by measurement of pressure in the combustion chamber.

In one version of this system, aspherical lenses are used to couple light (1) between the laser and the beam splitter and (2) between the optical fiber and the beam splitter. In another version, the aspherical lenses and the beam splitter are replaced by a unitary coupling/beam-splitting optic that consists of a hemispherical lens bonded to a 45° polarizing prism. The advantages of the latter version are that there are fewer



Laser Energy Heats the Ceramic Target, and black-body radiation from the target is measured to determine its temperature.

optical components that must be aligned with each other and efficiency is increased because the number of optical surfaces through which light must pass (and thus the amount of light lost in Fresnel surface reflections) is reduced.

This patent-pending device is available for license and can be used as a coupling optic for medical and industrial sensors, nearly lossless power summation and insertion of two diode lasers into a single fiber, read/write optics for optical disk drives, bidirectional fiber-optic communications, and wavelength division multiplexed fiber-optic communication.

In a typical application, this laser ignition system would be part of a closed-loop ignition-control system. A controller would command a laser power supply to operate at a set-point voltage that would correspond to a requested target temperature. The temperature signal from the photodiode would be used as a feedback signal to adjust the power-supply output to reduce any deviation from the requested target temperature.

The system is particularly attractive for use in applications in which there are requirements for one or more of the following characteristics: (1) ignition without contamination, (2) verification of operation of igniters prior to ignition, (3) compactness, (4) low power consumption, (5) low-voltage operation, (5) no accidental ignition, and (6) no electromagnetic interference. Examples of potential applications include jet engines, gas water heaters, furnaces, and industrial processing equipment that exploits high-purity combustion.

This work was done by David B. Duncan of Duncan Technologies, Inc., for **Johnson Space Center.** *For further information on the coupler, access* ***www.duncantech.com/tech_transfer.htm.***

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Judy Duncan, President
DuncanTech
11824 Kemper Road
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Refer to MSC-22872, volume and number of this NASA Tech Briefs *issue, and the page number.*


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Traveling-Wave Photomixer With Angle-Tuned Phase Matching

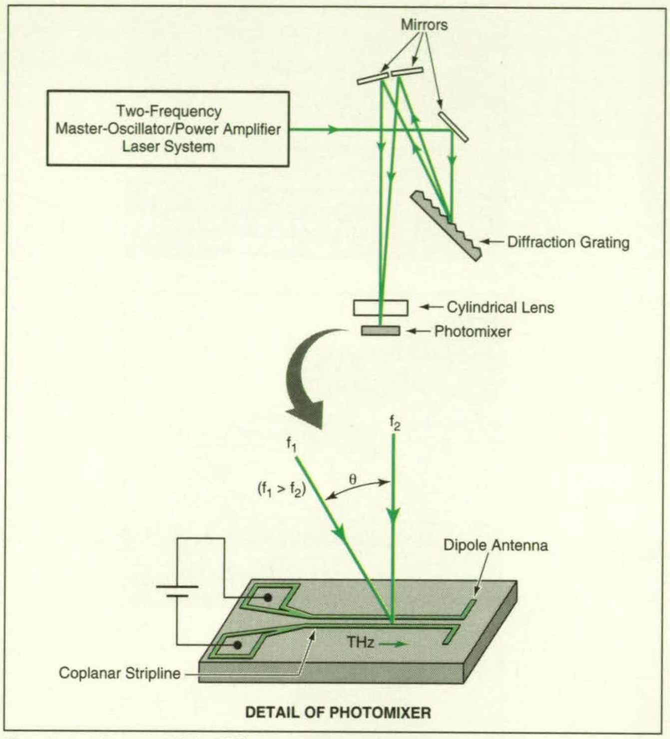
Relatively high terahertz output power can be generated at nondamaging laser power densities.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental traveling-wave photomixing device generates narrow-band electromagnetic radiation at frequencies up to a few terahertz. The device is, potentially, a prototype of terahertz local oscillators for heterodyne instrumentation for submillimeter-wavelength spectrometry and related scientific applications.

Devices that exploit traveling-wave photomixing to generate radio-frequency signals have been developed previously, but not for the terahertz frequency range. Conventional photomixers (that are not based on traveling waves) with terahertz outputs have also been developed previously, but have been limited as follows: In a conventional photomixer, the output power is proportional to the square of the photocurrent, and the bandwidth is limited by the lifetimes of photoexcited charge carriers and by the electrode capacitance. Therefore, such a photomixer must be designed to have (1) a narrow electrode gap for high photocurrent and (2) a small active area for small capacitance in order to obtain adequate bandwidth. Unfortunately, the smallness of the area of such a device limits its power-handling capability and thus its terahertz output power.

The present device is designed to overcome the limitations of conventional photomixers. It exploits a traveling-wave principle to distribute the generation of the terahertz signal over a relatively large area, so that a relatively large amount of power can be handled without exceeding the damage-threshold laser power density. Another essential element of the design is that the illuminated traveling-wave area is occupied by a transmission-line structure, which is not subject to the electrode-capacitance bandwidth limitation.



Two **Laser Beams With Different Frequencies** are aimed at the same device area at different angles to generate traveling difference-frequency charge-density waves accompanied by terahertz electromagnetic waves. Proper phase matching through adjustment of θ results in coherent superposition of the terahertz waves, which are then radiated by the antenna.

The device (see figure) consists of a dc-biased coplanar strip line terminated by an antenna fabricated on a low-temperature-grown GaAs film. The active area is illuminated by two laser beams that differ somewhat in frequency and are tilted at an angle with respect to each other in order to generate optical interference fringes that move along the strip line. The heterodyne mixing process generates charge-density waves that oscillate at the difference frequency and that are accompanied by terahertz traveling electromagnetic waves. If the velocity of the optical fringes and the group velocity of the terahertz waves are equalized, then the terahertz waves become coherently superposed and are effectively emitted by the antenna. For a given difference frequency, the angle between the two laser beams is adjusted to obtain the phase and velocity match needed for coherent superposition.

This work was done by Rolf Wyss and Shuji Matsuura of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category. NPO-20717*

Holographic Circle-to-Point Converter

Fabry-Perot interference fringes are focused to points for efficient detection.

Goddard Space Flight Center, Greenbelt, Maryland

The figure schematically depicts the use of a special-purpose holographic plate to focus light from (1) circular interference fringes generated by a Fabry-Perot etalon to (2) a series of points, each illuminated in a different wavelength interval. This holographic circle-to-point converter was invented to enable efficient utilization of the output light of a Fabry-Perot etalon in an incoherent Doppler lidar system. (The role of the etalon in such a system is to resolve, within a fairly narrow frequency band, the spectrum of light back-scattered by atmospheric particles that have been illuminated by a laser in the system.) If photodetectors are placed at the illuminated points to measure the intensities of light in the various wavelength intervals, then the photodetector outputs can be used to characterize the spectrum of light coming through the Fabry-Perot etalon.

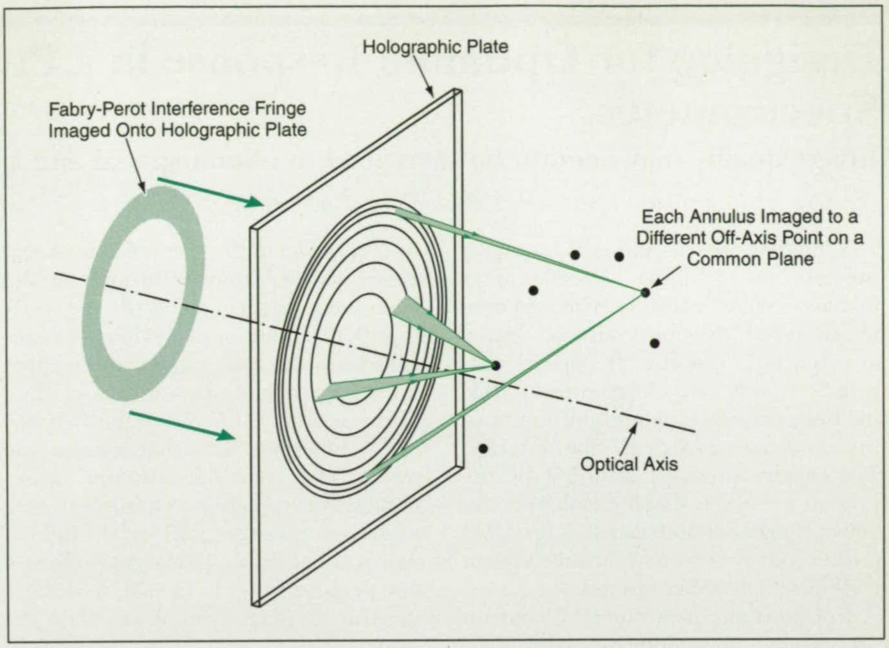
The role of the holographic plate is that of a field lens. As depicted in simplified form in the figure, the holographic plate superficially resembles a

Fresnel zone lens, but it does not function like one. The annuli in the holographic plate are designed to be registered with the annuli in the interference pattern, wherein successive annuli contain light in successive wavelength intervals. Unlike a Fresnel lens, the hologram in the plate focuses the light from each annulus to a unique off-axis point instead of to the center of the interference pattern.

The hologram can be constructed so that all annuli share a common focal length; that is, all the focal points lie on one plane that is parallel to the plane of the holographic plate. The number and sizes of annuli and the size of the holographic plate can be chosen to satisfy the design requirements for a specific instrument. In the example of the figure, the annuli of the holographic plate have equal areas to take advantage of the fact that equal areas in the circular Fabry-Perot interference pattern correspond to equal wavelength intervals; however, one could just as well use annuli with differing areas if a design called for unequal wavelength intervals.

This work was done by Vibart Stan Scott, Matthew J. McGill, and Marzouk Marzouk of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13869.



Concentric Circular Fabry-Perot Interference Fringes are imaged onto a plate that contains multiple holographic lenses. Although the holographic lenses are laid out concentrically, they focus light to different off-axis points.

Designing for Optimum Response in a Pushbroom Spectrometer

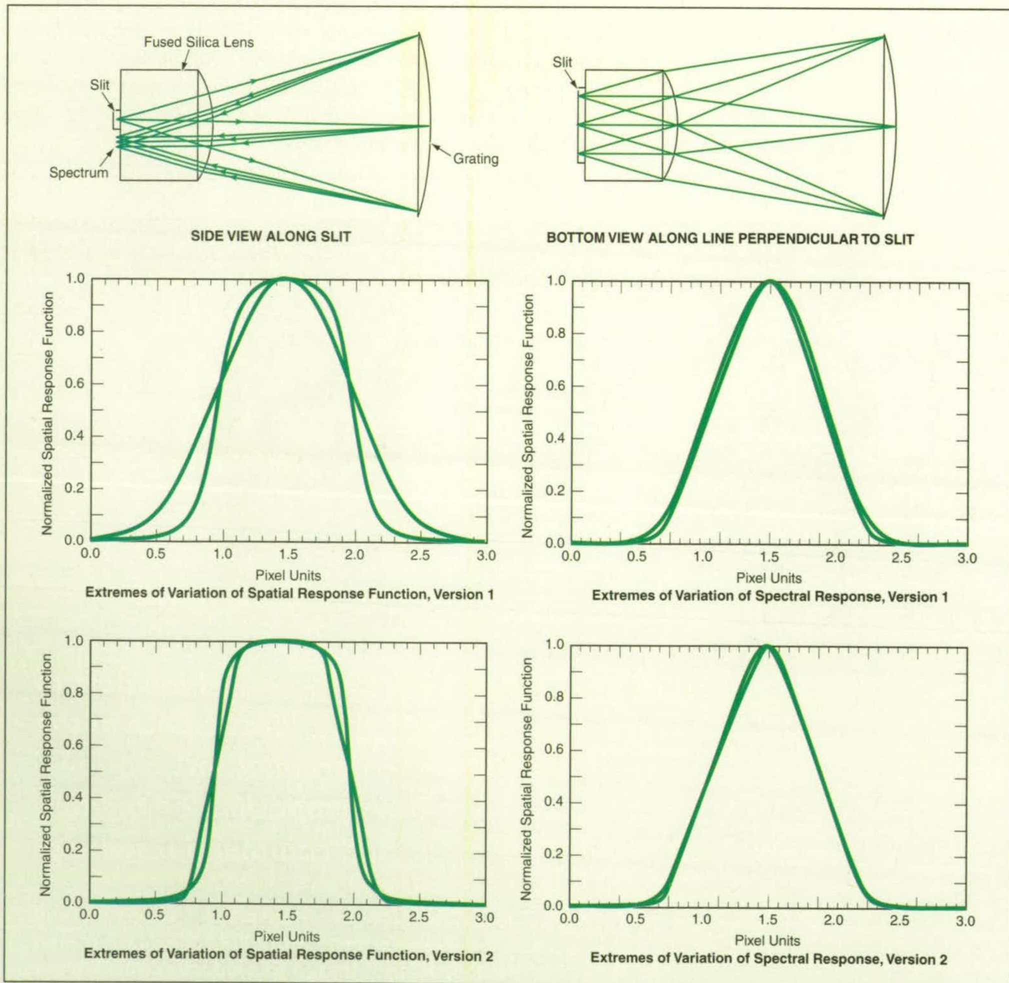
Image quality may need to be sacrificed to obtain spatial and spectral uniformity.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of designing a compact pushbroom imaging spectrometer includes explicit consideration and minimization of nonuniformity of spatial and spectral response. It appears that prior to the development of this method, the issue of nonuniformity of response was addressed haphazardly. The major advantage afforded by the present method is that it enables systematic optimization of the smallest possible pushbroom spectrometer within a given class of spectrometer designs.

A pushbroom spectrometer includes a rectangular photodetector array with pixels arranged in columns (parallel to a spatial axis defined by a straight slit) and rows (parallel to the spectral axis). Light enters the spectrometer through the slit. Each point or pixel along the slit corresponds to a point or pixel along one spatial axis in the scene under observation. Thus, each row of pixels gives a readout of the spectrum for one point or pixel on a columnar line that crosses the scene. The term "pushbroom" arises because in an action reminiscent of a pushbroom sweeping a floor, the field of view is swept through the scene, along a line perpendicular to the slit, to acquire spectral readouts from all pixels in the scene.

Heretofore, designers of pushbroom spectrometers have been concerned with optimizing spot sizes and minimizing distortions. While satisfaction of these design requirements is necessary, it is not sufficient. Even though spectral and spatial distortions might be minimized, there can remain variations in the spectral and spatial response functions that exert detrimental effects similar to those of spectral and spatial distortions. For complete optimization of design, it is necessary to seek a proper balance among all relevant measures of performance, including variations in spectral and spatial responses in addition to the customary measures of spot energy inside a pixel and spectral and spatial distortions.



A **Compact Dyson Spectrometer** has been designed to cover the wavelength range of 1,000 to 2,500 nm. Version 1 has been optimized with respect to distortion and image quality only. Version 2 has been optimized with respect to uniformity of response in addition to distortion and image quality. The two versions are similar, except that the distance from the lens to the grating is about 10 percent greater in version 2. In version 1, the variation of the spectral and spatial response functions shown negates the high degree of distortion correction achieved in the design and becomes the dominant source of spectral artifacts. In version 2, the spectral and spatial response function variation has been reduced to a very low level, compatible with the high degree of distortion correction achieved by the design.

The present method provides for optimizing design in the sense of choosing design parameters that yield an arbitrarily specified balance among all of the aforementioned measures of performance. The method is based partly on the theoretical observation that spectral and spatial response functions can be controlled through the spectrometer modulation transfer function (MTF) in their respective directions. (In the case of a spectrometer used to view the Earth from above the atmosphere, the effect of the atmosphere can be included, at least in an average way, by inclusion of an atmospheric MTF as mere multiplicative factor of the spectrometer MTF.)

In this method, an optimization (merit) function is constructed for use with an appropriate previously or subsequently developed optical-design computer program. The merit function contains specific spectral- and spatial-distortion components, spectral- and spatial-uniformity components, and spot-size components with appropriate weights between them. The optimization for uniform spectral response is based on equal-

ization of the MTF along the spectral axis, independent of field location. The optimization for uniform spatial response is based on either (1) equalization of the MTF along the spatial direction, independent of wavelength, or (2) achieving specified ratios among MTF values at various wavelengths.

In applications of the method to two generic spectrometer designs with only a few degrees of freedom, it was shown that optimally balanced specific designs can be obtained, even though the designs cannot be fully optimized to satisfy all requirements. In practice, one trades spot size to gain uniformity of response. This trade is demonstrated in the figure by comparison between two versions of one of these spectrometers.

This work was done by Pantazis Mouroulis, Robert Green, and Thomas Chrien of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20743*

Laser-Induced Rotation of a Levitated Sample in a Vacuum

Momentum is transferred by absorption of photons off center.

NASA's Jet Propulsion Laboratory, Pasadena, California

A high-power laser beam can be used to apply a torque to a sample of material that is electromagnetically and/or electrostatically levitated in a vacuum. The torque can be used to alter the state of rotation of the sample; this is an important capability because control of the state of rotation (or lack of rotation) can be necessary for processing the sample and/or measuring its properties.

In the usual case of an approximately spherically symmetrical sample, torque is generated by simply aiming the laser beam off center (see figure). It does not matter whether the sample is solid or molten, nor does it matter whether the sample is electrically conductive or nonconductive; this is because the torque-generating mechanism is simply the transfer of momentum to the sample from photons that impinge on the sample along a line that does not pass through the center of mass of the sample. The magnitude of the torque depends on the power of the laser beam, the fraction of incident photons absorbed (reflected photons do not contribute to torque), and the size of the moment arm.

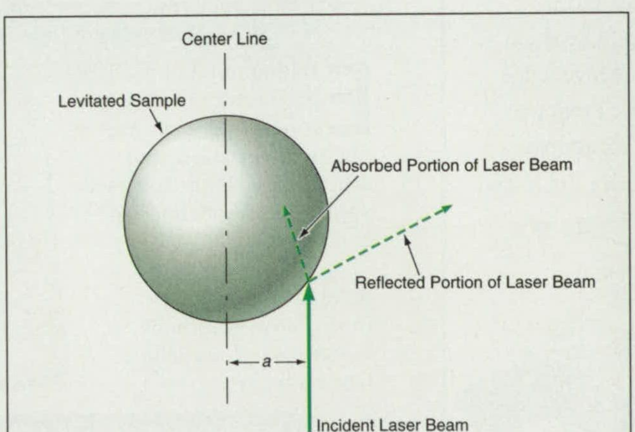
The magnitude of the torque can readily be estimated for the case in which the laser used to apply the torque to a spherical sample of mass m and radius R is the same laser used to heat the sample to a steady-state temperature, T. Assuming that the absorption and emission of radiation by the sample is governed by the Stefan-Boltzmann law, the torque (τ) is given by

$$\tau = 4\pi R^2 \sigma\varepsilon\, aT^4/c,$$

where σ is the Stefan-Boltzmann constant, ε is the hemispherical total emissivity of the sample material, a is the length of the moment arm, and c is the speed of light. The angular acceleration ($\dot{f}$) of the sample in this case is given by

$$\dot{f} = 5\sigma\varepsilon aT^4/mc.$$

This work was done by Won-Kyu Rhim and Paul-François Paradis of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20731*



The **Laser Beam Impinges on the Sample** off center. The torque imparted to the sample is proportional to the fraction of the beam power absorbed and to the length, a, of the moment arm.

New Products

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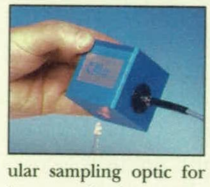
Product of the Month

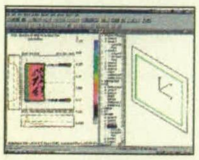
Real-Time Microscopic Imaging System

TNP Instruments, Carson, CA, is offering its DUV-250 imaging system, which it calls the first to combine microscopic resolution below one-quarter micron with real-time operation. TNP says the DUV-250, designed to fill the gap between visible-light and scanning electron microscopy, is a breakthrough for many high-tech applications, including microcircuitry manufacturing and medical research and testing. The device represents exclusive TNP developments in optical configuration and components and mercury arc-lamp illumination to achieve magnification of 25,000 ×. TNP says the DUV-250 typically operates at less than half the cost of traditional laser scanning systems.



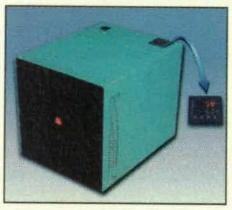
Fiber Optic Integrating Sphere

Ocean Optics, Dunedin, FL, says that its FOIS-1 fiber optic integrating sphere is a compact, modular sampling optic for spectral analysis of LEDs, lamps, and other emission sources. The unit collects light from a 180° field of view and funnels it to an optical fiber and spectrometer. Users can combine the FOIS-1 with Ocean Optics spectrometers and accessories for a system that measures absolute spectral intensity and color parameters of LEDs. The FOIS-1 is a highly Lambertian 1.5-in. Spectralon® sphere encased in a 2.25-×-2.25-×-2.125-in. aluminum housing. A 0.375-in.-diameter input port accepts light from 200-1100 nm, and an SMA connector couples an optical fiber from the sphere to a spectrometer.



Software for Lighting Display Analysis

Lambda Research Corp., Littleton, MA, has released an updated version of TracePro® optomechanical 3-D solid modeling software designed specifically to facilitate lighting and back-light display analysis. A new feature called RepTile™ gives TracePro the ability to design and analyze an entire LCD back-light larger than 50 mm in size, a first in the commercial software world, Lambda says. RepTile surfaces use a repetitive surface algorithm to create millions of conical bumps, dots, pyramids, Brightness Enhancing Films, and Fresnels on any planar surface.



Portable Infrared Blackbody Source

Electro-Optical Industries Inc., Santa Barbara, CA, introduces the ES1000-100 blackbody and temperature controller system. Rather than using a separate controller to regulate temperature settings, the ES1000-100 blackbody comes with a built-in controller installed in its housing. With an operational temperature range of 30 to 1000 °C, the unit is compact and portable, and weighs only 22 lbs. Its digital proportional, integral and derivative (PID) configuration yields a temperature stability of within 0.5 °C.

Fiber Optic Spectrum Analyzer

StellarNet Inc., Oldsmar, FL, offers a fiber optic spectrum analyzer for measuring the frequency and power output from laser diode and LED emission sources or transmission characteristics of optical materials. Several models and resolutions cover ranges in the UV, visible, and near-IR from 200-1600 nm. The SpectraWiz® software for Win 9X/NT provides measurement tools for wavelength peak, FWHM, centroid, spectral density, and transmission characterization displays. Two configurations are available, including the portable EPP2000.

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Vol. 25, No. 1 January 2001 This form expires: June 2001

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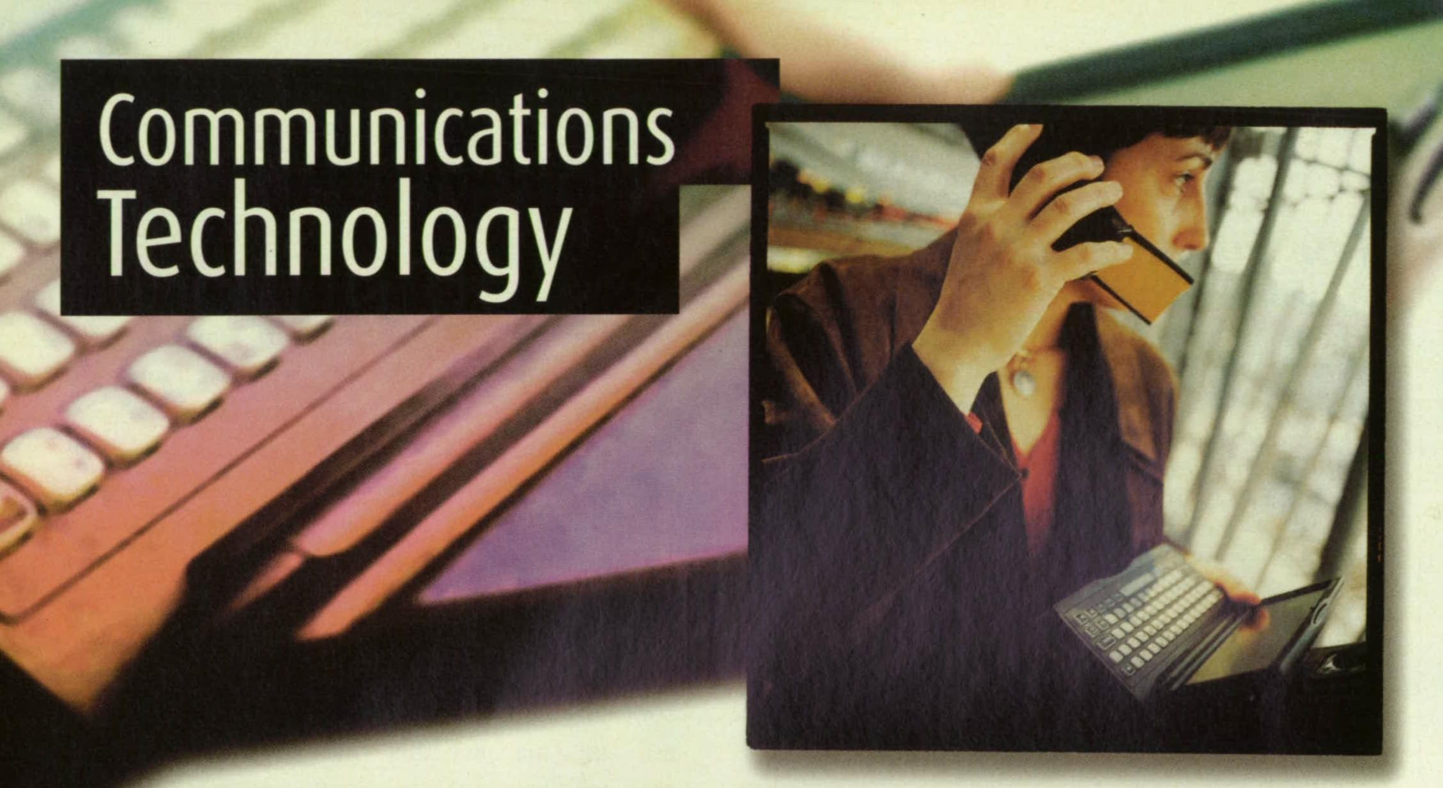
Communications Technology



Cellular phones have changed the way most of us live and work, but they are just the beginning. With the proliferation of the Internet, and mainstream use of laptop and handheld computers, the methods we use to communicate also are changing at a rapid pace.

Communications technology today encompasses everything from cell phones and personal digital assistants (PDAs), to networking, the Web, and teleconferencing. But whether you're scheduling meetings on your handheld computer or collaborating with colleagues via the Internet, communicating still means getting information from point A to point B.

In the new century, when you think about how people communicate, the first word that comes to mind is wireless, whether you're sending voice or data. According to research firm Allied Business Intelligence, the number of wireless subscribers worldwide rose to 477 million at the end of 1999. But by the end of 2004, that number is expected to jump to 1.1 billion. And with the recent boom in Bluetooth™ technology, wireless communication soon could be virtually ubiquitous.

Wireless at Work

Workers — including engineers — no longer are chained to their desks, or their workstations. In fact, estimates indicate that there are 45 million mobile workers in the US. Where cell phones once were the method of choice for staying in touch with the office, the use of e-mail and the need to transfer and access data have helped to increase the use of wireless data communication.

Mobility is the key, whether engineers are using paper and pen or laptop computers to perform their field work. Wireless handheld devices such as PDAs are no longer just trendy consumer electronics. They are becoming the method of choice for organizations — including NASA, the US Army, the US Navy, hospitals, banks, and airlines — to communicate. By providing easily accessible electronic versions of forms, databases, checklists, calendars, and other critical data, wireless devices give users the ability to get — and stay — connected to their jobs and to each other.

NASA has taken wireless communication to a new level with a "voice over the Internet" solution for communicating with the International Space Station (ISS). CU-SeeMe® Web and MeetingPoint™ video conferencing software products from White Pine Software are providing verbal communication between NASA sites around the country and the ISS via the Internet in real time. The project is tied into the Payload Operations Center at NASA's Marshall Space Flight Center in Huntsville, AL. White Pine's technology is integrated into a custom web interface that is used as a central communications center for NASA.

Handheld computers are replacing clipboards and pens for data collection, and also are serving as reference manuals for sailors aboard US Navy and Army submarines, aircraft carriers, and ships. The military is using wireless data communication devices to capture flight-deck data, fill out requisition forms and crew schedules, and download work orders from a local area network (LAN).

State-of-the-art medical centers such as Cedars-Sinai are using Palm™ handheld computers to wirelessly communicate everything from lab results and patients' surgical reports to admitting histories and consultation information. Instead of relying on written charts, doctors are able to securely obtain remote access to clinical information that is located on a variety of servers. Physicians also can exchange e-mail with colleagues in the same hospital or around the world to help better diagnose patients.

Getting and Staying Connected

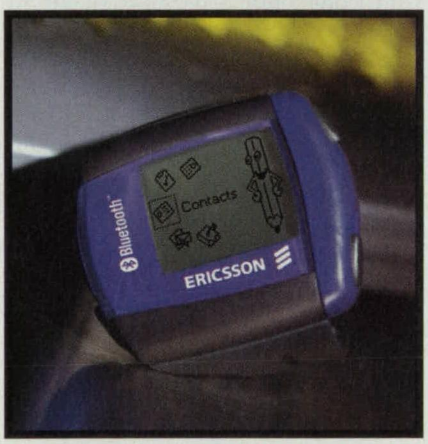
So you use a cellular phone, a PDA, and a laptop computer. How do you connect all of them together to be able to transfer data back and forth among all three? What about wirelessly connecting your laptop to the Internet? A variety of new and potentially revolutionary technologies are making all of this possible.

The Wireless Application Protocol (WAP) is an emerging standard for delivering wireless information and telephone service to mobile phones and other wireless devices. With WAP-enabled devices, you can access your company's WAP-

supported intranet, and connect to e-mail, databases, or other servers. Companies such as Hewlett-Packard have already introduced WAP-enabled platforms built on their servers that run UNIX and Windows NT. Other vendors, including Cisco Systems and IBM, are rolling out WAP-based products as well.

But there's a catch. The technology is still in its infancy, and compatibility is still a problem. Not all WAP browsers and gateways are compatible, so if companies do not standardize on one WAP phone or use compatible gateways, transferred data won't be readable. There is, however, a WAP 1.1 standard that will be used for product certification so that all vendors can become compatible.

Designers of equipment in the telemedicine, monitoring, industrial controls, and remote data collection industries can now use Connect One's peripheral chip called the iChip™ Internet Controller™ to embed Internet connectivity for devices via wireless Global Systems for Mobile (GSM) communications modems. The chip works with a device's



There are more than 50 qualified Bluetooth-enabled communication devices on the market today, with that number growing steadily.

host processor to mediate the connection between the host CPU and the Internet, enabling Internet access via any Internet service provider.

iPlanet™, a Sun-Netscape Alliance, offers its Intelligent Communications Platform, an extensible software platform that delivers communication and collaboration services over combined voice, wired, and wireless networks. This Internet Service Deployment Platform runs on top of a traditional operating system and hardware base. The software provides the ability to deliver existing communication services such as e-mail via wireless protocols to multiple devices. iPlanet's Wireless Server provides the basis for wireless calendaring, messaging, and directory services to WAP-enabled cell phones and laptops.

The Bluetooth Revolution

The result of technical achievements by 3Com, Ericsson, Intel, IBM, Lucent, Microsoft, Motorola, Nokia, and Toshiba, the Bluetooth™ wireless technology is poised to change the way we stay connected. Bluetooth is a low-cost, low-power, short-range wireless radio technology that links mobile phones, PDAs, laptops, and other portable devices. And while Bluetooth-enabled devices are just beginning to get to market, the applications for the technology are booming.

Let's say you're out of the office and you need to use your mobile computer to access the Web. With Bluetooth, you can surf the Internet, whether you're cordlessly connected through a mobile phone or through a wire-bound connection such as a LAN. Exchange files between two mobile computers without connecting cables. In meetings, you can transfer documents instantly to selected participants and exchange electronic business cards automatically without any wired connection. Automatically synchronize your desktop PC, laptop, PDA, and mobile phone.

Bluetooth operates in the same 2.45 GHz frequency band worldwide, so your Bluetooth devices will function whether you're in the United States, Asia, Europe,

or anywhere else on Earth. Since it is a radio-based technology, it does not require line-of-sight between devices for communication.

The ability to connect your cell phone to any mobile computing device is the initial application of Bluetooth. But according to marketing consultant Frost & Sullivan, as the installed base of Bluetooth-enabled devices grows, users will be able to quickly and easily communicate information, and that infrastructure will result in a host of new applications and services.

The Bluetooth Special Interest Group (SIG) now has more than 2,000 manufacturers that have joined to offer Bluetooth-enabled products. While telecommunications and computers were the first industries interested in this new technology, other industries such as automotive, data acquisition, test and measurement, industrial automation, and electronics are looking to incorporate Bluetooth's versatility. SIG has developed the Bluetooth Specification, a de facto standard containing the information required to ensure that diverse devices supporting Bluetooth can communicate with each other worldwide.

Recent additions to the Bluetooth-enabled device market include offerings from Intel, Mi-Co, and Extended Systems, which introduced a software development kit for implementing Bluetooth wireless protocols in handheld devices. Version 1.1 of XTNDAccess™ Blue SDK is used in developing embedded devices such as cellular phones, PDAs, portable office equipment, digital cameras, medical equipment, and industrial automation products.

Mi-Co (Mobile Internet Corporation) has developed a Bluetooth-enabled version of its pen-on-paper solutions, which are a combination of hardware, software, and application services. They include Mi-NotePad™ that enables handheld mobile device users to digitally capture and store handwriting and sketches. Mi-Messages™ lets users transmit this information wirelessly — via standard e-mail applications — to other PDAs, PCs, faxes, and other devices.

Test and measurement instrument manufacturers such as Keithley Instruments, Celerity Systems/L-3, and Agilent Technologies recently introduced Bluetooth test and measurement instruments and peripherals. Intel is shipping Bluetooth hardware and a complete Bluetooth software suite, and they plan to ship mobile computers with the Bluetooth wireless technology later this year.

Agilent's new line for manufacturers and designers of electronic devices includes a standalone Bluetooth communications test set, a spectrum analyzer, and new generator capabilities. According to George Sparks, vice president of Agilent's Wireless Market Solutions Unit, "Bluetooth is the wave of the future. Over 2,000 companies have registered to use the technology, and we can expect a proliferation of Bluetooth devices. Agilent has worked closely with the Bluetooth Special Interest Group on the standard's testing section, which has given us an appreciation for the complexity of Bluetooth testing."

While cellular phones have changed the way most of us live and work, they are just the beginning. The technologies we've covered here, along with the proliferation of the Internet, will continue to change the methods we use to communicate.

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Allied Business Intelligence
www.alliedworld.com

Bluetooth™ Special Interest Group
www.bluetooth.com

Celerity Systems/L-3 Communications
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Cisco Systems
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Connect One
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Keithley Instruments
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Mi-Co
www.mi-corporation.com

Palm, Inc.
www.palm.com

White Pine Software
www.wpine.com

SmartSketch LE Version 3

Steven S. Ross

Only the name is confusing about SmartSketch LE. This is a 2D drafting program from Intergraph's Process & Building Solutions division. SmartSketch works like many competitors' programs, but it has a bunch of twists that make it special. For instance, it can automatically turn rough sketching into arcs and lines. They are true CAD entities — not collections of tiny polylines that might look like an arc on the screen but not behave that way in the drawing. SmartSketch can also handle true intelligent symbols — a process that is closer to Visio and to Autodesk's Actrix than to a standard CAD program. The symbols' dimensions can be modified on the fly through a spreadsheet or Mathcad-driven calculation. All this makes the package a delight to use in an industrial setting, where casual, occasional drafters often need to sketch or draft just a few new parts while adding many standard parts and assemblies from a symbol library.

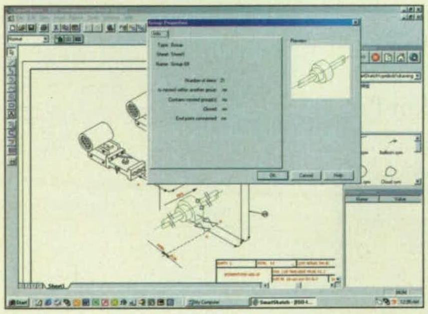

Figure 1: This assembly has 21 items within it. You highlight on the drawing and right-click to display properties.

Now, about that name. If this product sounds similar to earlier Intergraph products such as Imagineer and Imagination engineer, it should. Intergraph changed the name after Disney pointed out that it already coined the term "imagineer" for its designers of attractions. This is the lightweight edition of SmartSketch 3.0, which was released late in 1999. It comes at a lightweight price, just $99, whereas SmartSketch lists for $495. You can buy it online, or download a demo free, from http://www.SmartSketch.com/pbs.

Everything behaves the way casual drafters — people who don't sit in front of a CAD terminal eight hours at a stretch —think they should. The symbols connect to each other in logical ways, rotating to fit as needed. As you draw connectors, everything lines up. The symbol modules come with extra drafting and positioning tools unique to their specific discipline, and the icons show up on screen automatically. Symbol dimensions can be driven from the geometry, or can drive the geometry of the drawing.

SmartSketch LE also works well with Microsoft Office and other Windows packages — it is an OLE 2.0 client and server.

Intergraph sells a number of add-on modules for the LE version. You can buy the module for translating to and from AutoCAD (R10 through 2000) DWG and DXF and MicroStation DGN (V4, 5, SE) for $149. If the files you work with contain raster data as well as vector, however, you'll also want the ImageScape LT module for another $99. The CAD translator without ImageScape opens files with raster images inside, but does not translate them into SmartSketch files. ImageScape handles GIF, JPG, bitmap, TIF, and a dozen other formats. Symbols for electrical diagramming (250 component symbols and 200 control symbols) are another $99. The geometric dimensioning and tolerancing module, with 144 weld symbols, is $49 (metric and English templates included). You can publish your designs to the Web with another $49 module. The 2,800 process symbols are a hefty $249.

Thus, if you need more than one or two modules, you'd probably be better off buying the full version of SmartSketch; it comes with the modules built in, and includes hooks for your own VisualBasic and other ActiveX tools, architectural, HVAC, and site planning tools not available as separate modules, and a report generator for bills of materials. The full version also has better isometric drawing tools. You can start with the $99 LE package and upgrade to the full SmartSketch for $396, so you don't lose anything in the process. As we went to press, in fact, the upgrade was only $295.

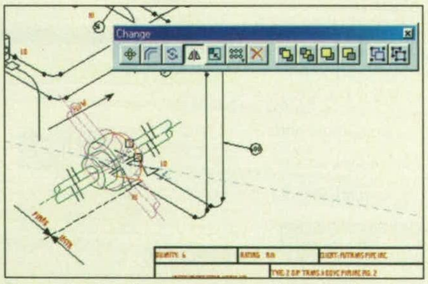

Figure 2: You don't get to modify an object in a drawing unless you specifically click on the "change" icon and use the Change toolbar.

We used the translation module to move files back and forth between SmartSketch LE and AutoCAD. The translations are near perfect. But there is a trap: As with Autodesk's Actrix itself, smart symbols lose most of their "intelligence" when moved into an AutoCAD DWG file, and AutoCAD DWG "smart" objects (drawn with Mechanical Desktop or Architectural Desktop) lose their intelligence inside SmartSketch. This lack of true compatibility in Autodesk products — and in Visio and MicroStation for that matter — puts a premium on a package that can handle both drafting and symbols. SmartSketch is just that.

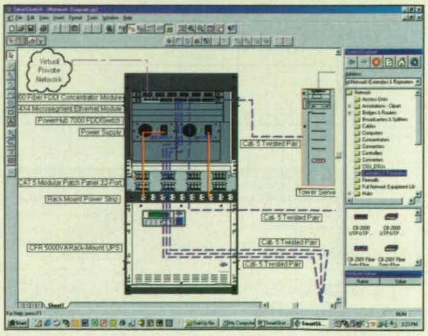

Figure 3: Enlarged area of a block diagram of a network. Notice the symbol viewer on the right.

Requirements are a Pentium 133 MHz or higher; 64 MB RAM; SVGA or better screen (800 x 600); and Windows 95, 98, NT 4.0, 2000, ME. We tested on an absolute minimum machine — a 133-MHz Windows 95 laptop — and it ran well. But it flew at 733 MHz with 256 MB of RAM under Windows 98 SE. The LE version and all six modules can be downloaded from Intergraph. A demo download of LE itself is free. Support is free through e-mail, or $30 per phone call.

Steve Ross reviews software bimonthly for *NASA Tech Briefs*. He runs the science writing program at Columbia University's Graduate school of Journalism in New York City, ran an educational and computer graphics software firm in the mid-80s, and has written 18 books and three engineering software packages.

Flat-Panel Displays Will Be Astronauts' "Eyes"

Warrior Vision™ flat-panel displays
Interstate Electronics Corp./L-3 Communications Corp.
Anaheim, CA
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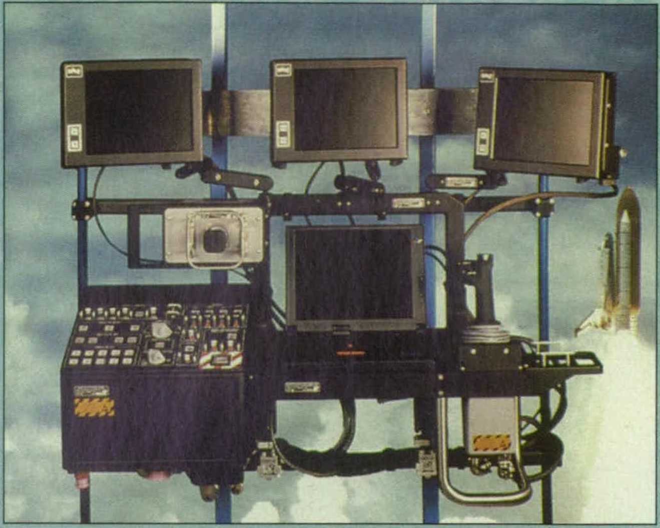


Scheduled for launch to the International Space Station's Robotic Workstation (RWS) in 2002, the Warrior Vision displays will be used as a visual reference to control the station's sophisticated robot arm. The displays will help astronauts accomplish tasks such as manipulating large payloads and satellites, and assembling projects that are too big to be launched from Earth. Two systems will be located on the space station in the pressurized Lab Module, and one will be in the Cupola, where astronauts can perform maintenance on the station itself.

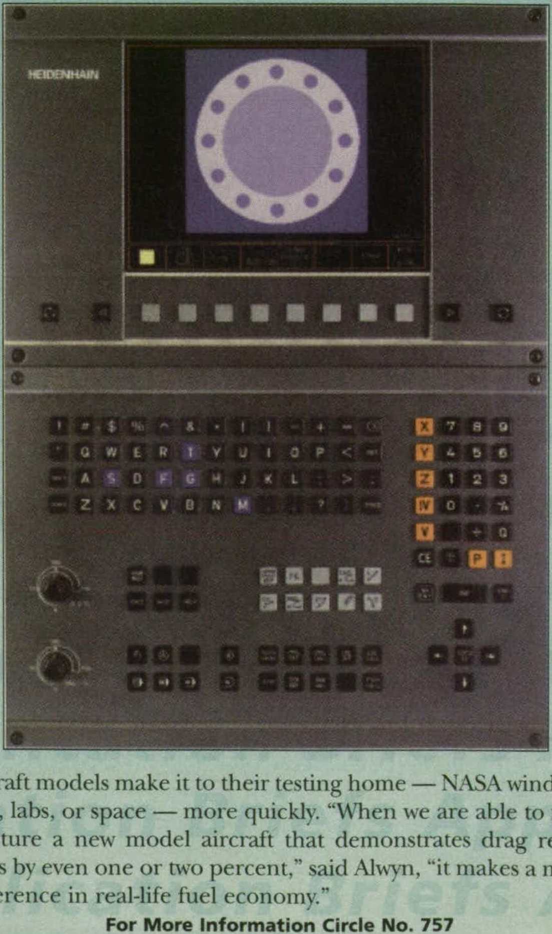
The displays are active matrix liquid crystal displays with 640 x 480 resolution, and have a mean time between failure rating of 13,000 hours. Each display will be integrated with special software to provide visual feedback from the space station's Remote Manipulator System, Special Purpose Dexterous Manipulator, Mobile Base System, and Artificial Vision Unit.

Ruggedized to accommodate the stresses of launch into space, the displays meet NASA's severe operational, weight, and environmental requirements. "Our displays can be found among the most demanding climates and conditions on Earth," said Steve Jungers, vice president at L-3/IEC, "and now we're in space."

For More Information Circle No. 756

NASA Incorporates CNC System In Facility Retrofit

Heidenhain TNC 426 machine control system
Heidenhain Corp.
Schaumburg, IL
847-490-1191
www.heidenhain.com



The Developmental Machining and Electromechanical Instrumentation Branch (FMX) at NASA's Ames Research Center in Moffett Field, CA, recently retrofitted the department's entire milling centers with new computer numerical control (CNC) technology. According to James Alwyn, chief of the FMX branch, "Machining technology has evolved to a new level in recent years, and we had to be right at the top of it." Up until a few years ago, the department had mills with various controllers on them, from different manufacturers, and the oldest one dated back to 1968.

NASA incorporated Heidenhain's TNC 426 controls, linear scales, touch probes, and remote hand wheels for its multi-axis machines. The system provides a large memory capacity, user-friendly programming features, fast block time processing, and absolute positioning capability. All of these features were important to Alwyn for the precision aircraft model machining performed at the FMX branch. "We do machining here that is unique to most manufacturing operations. I would say mold machining most closely resembles our work, but in a rudimentary way. It is important that we have very advanced programming capabilities and machine control," explained Alwyn.

The retrofit provided improved accuracy, reliability, and speed, making the FMX branch more efficient. As a result, aircraft models make it to their testing home — NASA wind tunnels, labs, or space — more quickly. "When we are able to manufacture a new model aircraft that demonstrates drag reductions by even one or two percent," said Alwyn, "it makes a major difference in real-life fuel economy."

For More Information Circle No. 757

Commercialization Opportunities

Submillimeter-Wave Image Sensor

Sensors of this type could offer new capabilities for analysis of radiation from far-infrared devices, measurement of the radiative properties of materials, molecular-line spectroscopy of astronomical bodies, and possibly imaging of biomaterials for medical applications.
(See page 36.)

Wireless-Communication Headset Subsystem To Enhance Signaling

A special-purpose communications subsystem provides a push-to-talk signal to a communication system as if the individual was directly wired to the system. This interface operates in the 900-MHz industrial, scientific, and medical frequency band.
(See page 44.)

Power Amplifier With 9 to 13 dB of Gain From 65 to 146 GHz

A three-stage power amplifier is capable of operating without tuning over a wide frequency band ranging well above 100 GHz. There is a growing need for these circuits in radar, imaging, scientific instrumentation, and communications.
(See page 44.)

Humidity Interlock for Protecting a Cooled Laser Crystal

This interlock had been developed to prevent damage to an expensive laser crystal that must be maintained at a temperature below ambient during operation. Whenever humidity rises, the interlock turns off power to a thermoelectric cooler on which the crystal is mounted.
(See page 46.)

A Lightweight Ambulatory Physiological Monitoring System

This biomedical instrumentation package features high data quality, ease of operation, minimal time to set up, and comfort and mobility greater than in similar systems.
(See page 48.)

Broad-Band, Noninvasive Radio-Frequency Current Probe

This instrument measures alternating current over a broad frequency band. It could be especially useful for assessing radio-frequency hazards by measuring currents in personnel exposed to radio-frequency electromagnetic fields.
(See page 50.)

Flow-Concentrating Supersonic Gas/Liquid Nozzles

The overall function of these nozzles is to generate concentrated two-phase flows, which are highly effective in cleaning surfaces of tanks, pipes, tubes, machine parts, and structures.
(See page 60.)

Slide-Staining System for Microgravity or Gravity

This conceptual self-contained system would be automated, eliminating routine and tedious processing steps. On Earth, such a system could be useful in remote medical research field stations, field hospitals, and biomedical research facilities.
(See page 64.)

Submillimeter-Wave Image Sensor

For the first time, it would be possible to perform heterodyne imaging at frequencies >100 GHz.

NASA's Jet Propulsion Laboratory, Pasadena, California

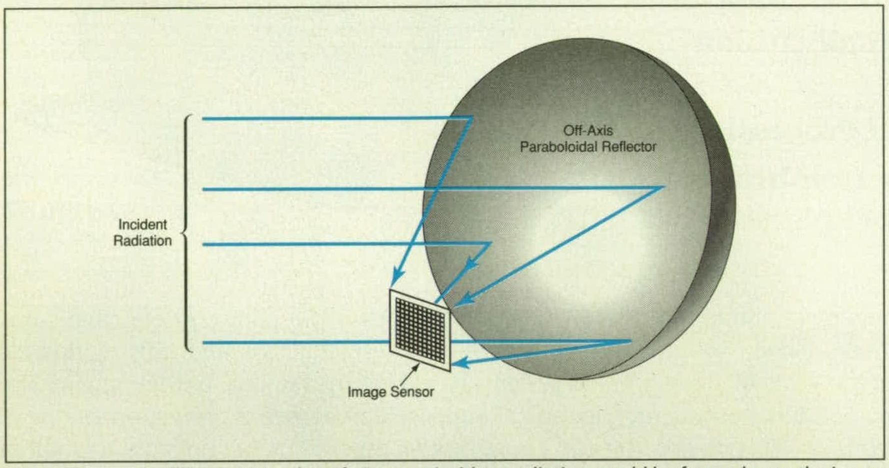


Figure 1. In a **Submillimeter-Wavelength Camera,** incident radiation would be focused onto the image sensor, which would contain a grid of closely spaced dipole antennas and associated detector circuitry.

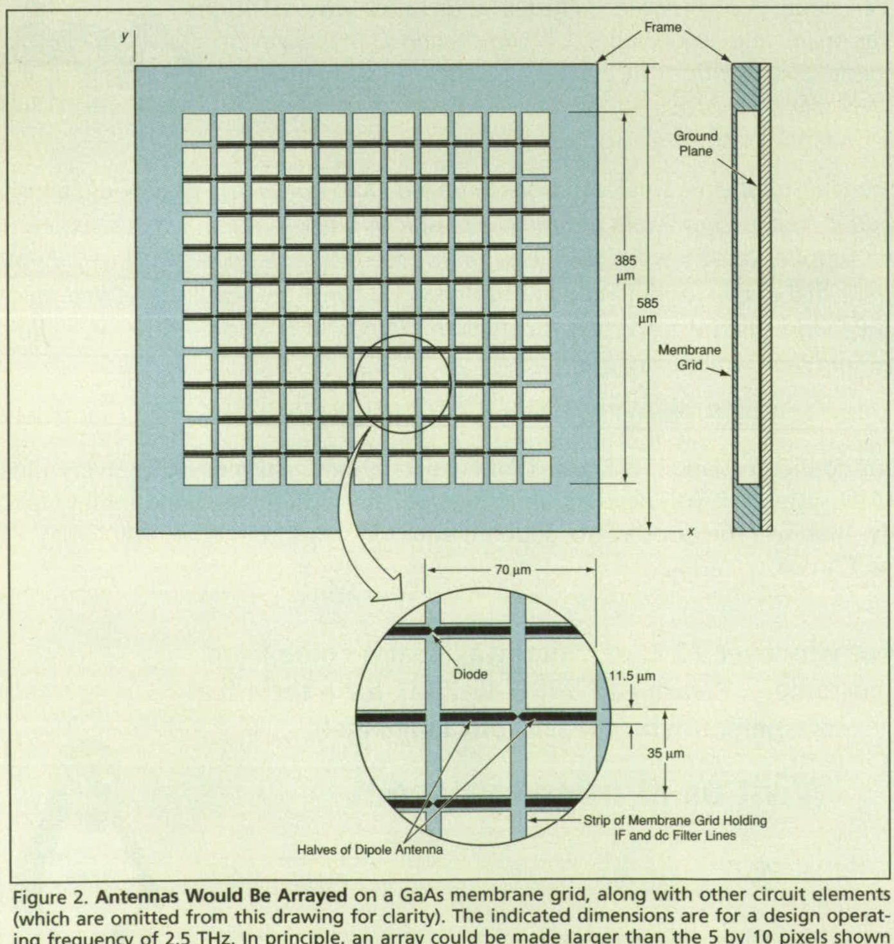


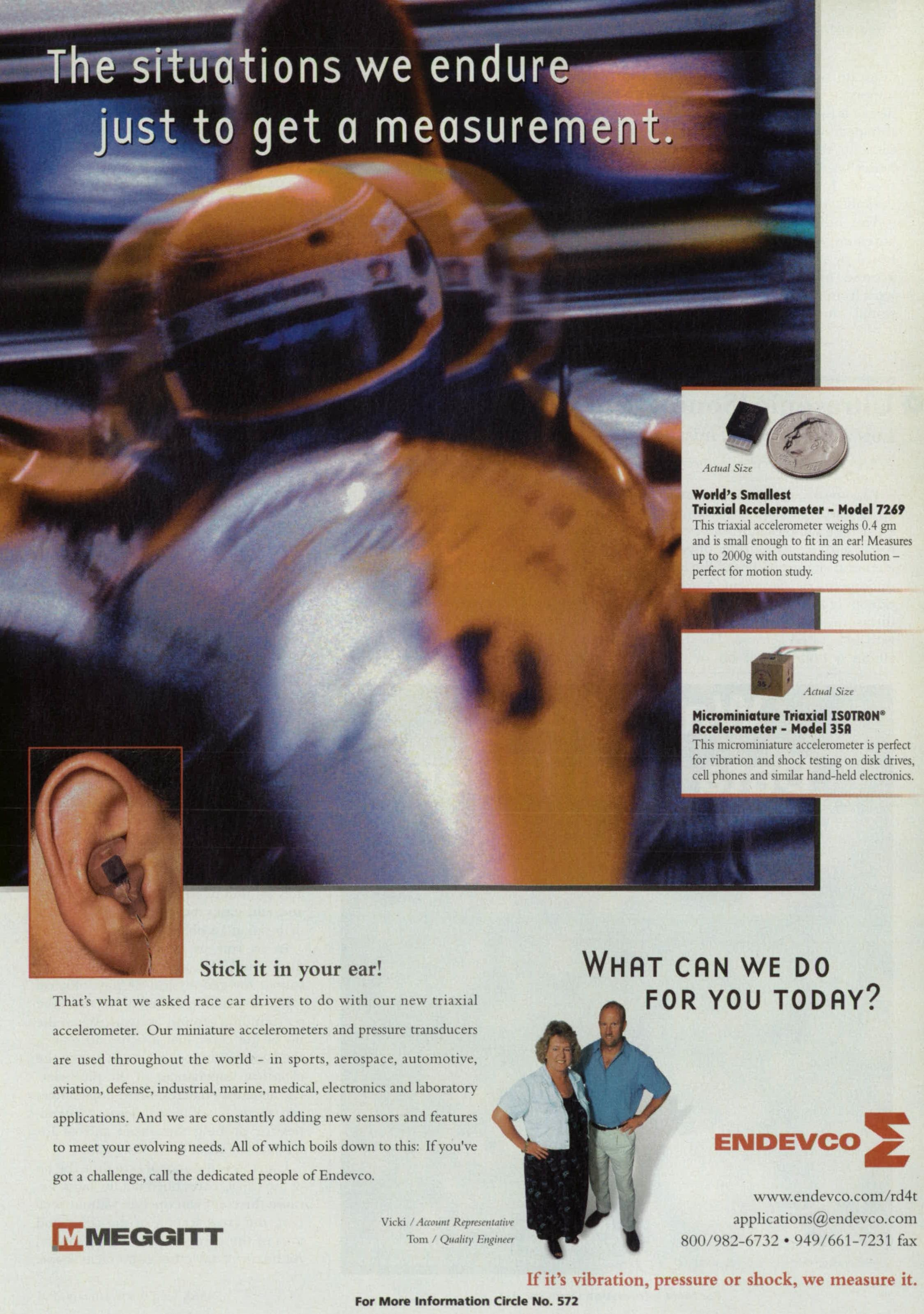
Figure 2. **Antennas Would Be Arrayed** on a GaAs membrane grid, along with other circuit elements (which are omitted from this drawing for clarity). The indicated dimensions are for a design operating frequency of 2.5 THz. In principle, an array could be made larger than the 5 by 10 pixels shown here; the practical upper limit on size (several square millimeters) depends on the strength of the membrane grid.

A proposed monolithic planar array of miniature dipole antennas, diodes, and associated input/output circuitry would serve as a prototype of image sensors for submillimeter-wavelength video cameras (see Figure 1). Sensors of this type could be designed to operate as either direct or heterodyne detectors of electromagnetic radiation at frequencies from 300 GHz to 3 THz; as such, they could offer new capabilities for such diverse uses as analysis of submillimeter radiation from far-infrared devices, measurements of the submillimeter-wavelength radiative properties of materials, molecular-line spectroscopy of astronomical bodies and the upper atmosphere of the Earth, and perhaps imaging of biomaterials for medical applications.

The development of the proposed submillimeter-wave image sensor would extend the recent development of a single high-sensitivity, 2.5-THz heterodyne Schottky-diode mixer based on a monolithic membrane diode (MOMED) micromachined in GaAs. The dipole antennas, diodes, and other circuit elements would be formed on a 3-μm-thick, epitaxially grown GaAs membrane grid that would be suspended from a relatively thick GaAs frame (see Figure 2). The antennas would lie within a quarter wavelength of each other (the diffraction limit) in the *y* axis, and the rows of antennas would be staggered along the *x* axis for partial filling in of nonoverlapping pixels.

Associated with each antenna would be a Schottky diode for detection and/or down-conversion, plus a low-pass radio-frequency filter transmission line for supplying dc bias and removing and distributing the low-frequency products of detection and/or down-conversion. The filters would be closely coupled high-and-low-impedance transmission lines that would provide open circuits at the input signal frequency near the antenna terminals.

The frame, the membrane grid, and the antennas, diodes, and other circuit elements, would be fabricated simultaneously, all as parts of a monolithic unit, by micromachining from GaAs in a process similar to that used previously to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fabricate the single 2.5-THz mixer. An important feature of the membrane-grid design is that the antennas would be surrounded mostly by airgaps, which would serve to reduce circuit losses, provide better beam efficiency, and make it impossible for radiation to propagate undesirably in substrate modes.

The otherwise bidirectional dipole antennas would be rendered unidirectional by incorporation of a reflecting ground plane a quarter wavelength back from the membrane surface. Additional intermediate-frequency (IF) and/or dc circuitry could be incorporated on the back of this ground plane, GaAs frame, and/or on the GaAs membrane grid, whichever is more convenient. The circuitry on the GaAs chip could be connected to external dc and IF circuitry through contact pads on the GaAs frame.

This work was done by Peter Siegel of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20718, volume and number of this NASA Tech Briefs *issue, and the page number.*

Ultrasonic/Sonic Drill/Corers With Integrated Sensors

Low-reaction-force, misalignment-tolerant corers double as sensory probes.

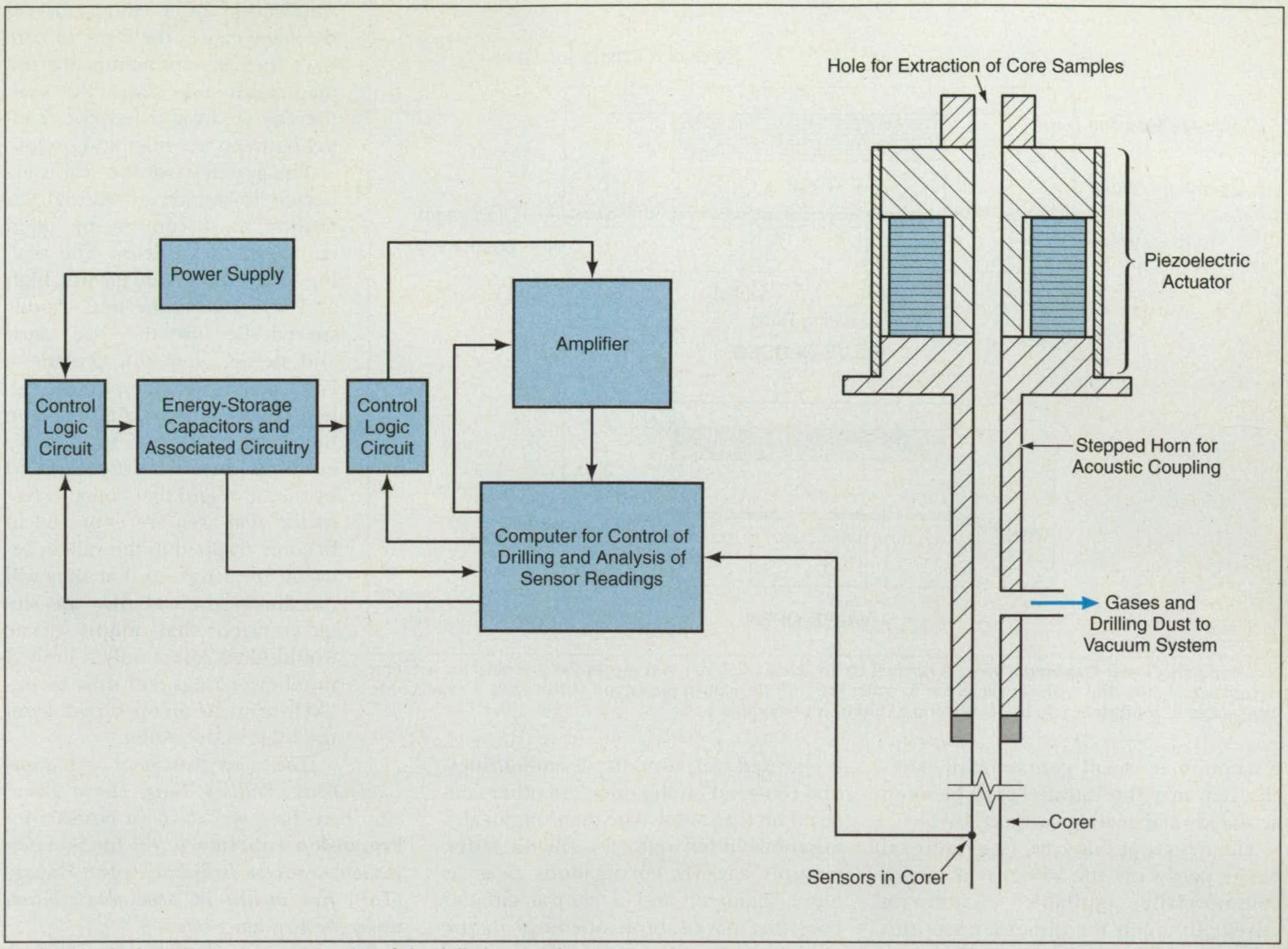
NASA's Jet Propulsion Laboratory, Pasadena, California

Easy-to-use, low-power-consumption apparatuses capable of drilling to acquire core samples of thick layers of material and/or measuring physical and chemical characteristics of the layers are undergoing development. A major component of an apparatus of this type is an ultrasonic/sonic drill/corer (USDC) with integrated sensors. The USDC includes a hollow drill bit or corer, in which a combination of ultrasonic and sonic vibrations are excited by an electronically driven piezoelectric actuator. The corer can be instrumented with a variety of sensors for both probing the drilled material and acquiring feedback for control of the excitation (see figure). The potential uses of these apparatuses are so numerous that it is not possible to list them all here; a few representative examples include sampling rocks and soil, medical procedures that involve core sampling and/or probing, detecting buried land mines, and even extracting rock cores for use as small bricks.

The USDC advances into the material of interest by means of a hammering action and a resulting chiseling action at the tip of the corer. The combination of ultrasonic vibrations (typically at a frequency of ≈20 kHz) and sonic vibrations (typically at a frequency between 60 Hz and 1 kHz) gives rise to a hammering action that is more effective for drilling than is the microhammering action of ultrasonic vibrations alone. The hammering and chiseling actions are so effective that unlike in conventional twist drilling, a negligible amount of axial force is needed to make the USDC advance into the material. Also unlike a conventional twist drill, the USDC operates without need for torsional restraint, and can easily be made to drill into a material at an oblique angle.

In its role as a hammering mechanism, the USDC also acts as a sounding source for geophysical or physiological sonar to examine drilled objects and the surrounding ground or tissue. When the tip of the corer first touches an object, the acoustic impedance (and hence the electrical impedance) of the piezoelectric actuator changes; these impedances can serve as additional sensory quantities for probing the object and/or for feedback control of the excitation.

Unlike a conventional twist drill, the tip of the USDC corer need not be sharp. Because the corer can operate without rotation, the cross section of the corer and thus of the core samples can be square, round, or of any other convenient shape.



The **Sensors in the Corer** measure properties of the drilled material.

The corer vibrates transversely as well as longitudinally, causing the formation of a hole somewhat wider than the corer; consequently, unlike a conventional twist drill, the USDC resists jamming and is highly tolerant of misalignment.

At a location away from the tip of the corer, the hollow interior of the corer can be connected to a vacuum system via a tube. This connection can be used to extract drilling dust and gases emitted by the drilled material for analysis. The sensors in the corer can be used to determine various properties as functions of depth. Examples of sensors that could be integrated into the corer include accelerometers, acoustic transducers (in addition to the piezoelectric actuator) to measure mechanical properties, eddy-current sensors to measure electromagnetic properties, fiber-optic probes to examine the newly exposed surface, temperature sensors, and electrodes made of various materials to obtain measures of chemical reactivity.

This work was done by Yoseph Bar-Cohen, Stewart Sherrit, Benjamin Dolgin, Thomas Peterson, Dharmendra Pal, and Jason Kroh of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*
NPO-20856

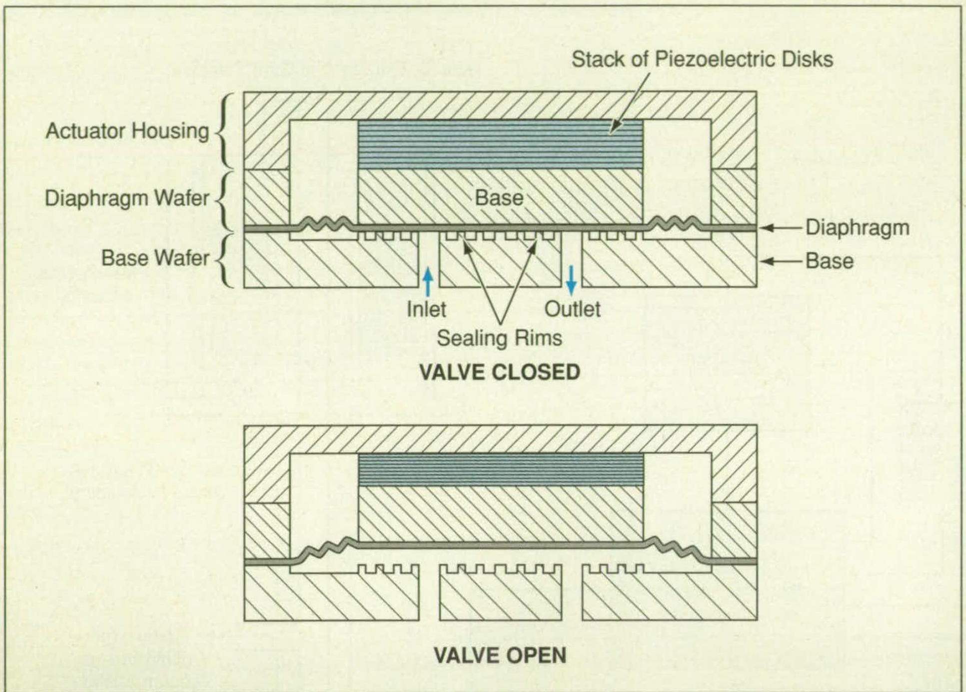
Normally Closed, Piezoelectrically Actuated Microvalve

Care is taken in design and fabrication to ensure a low leak rate.

NASA's Jet Propulsion Laboratory, Pasadena, California

A normally closed, piezoelectrically actuated microvalve is being developed as a prototype of valves in microfluidic systems and other microelectromechanical systems (MEMS) intended for operation in outer space. Terrestrial MEMS in which such valves could also prove useful include implantable pumps to administer precisely metered medications, controllers for tightly regulating flows of chemicals in semiconductor-manufacturing processes, and flow controllers for environmental and biological monitoring systems.

Like other devices originally intended for use aboard spacecraft, the present microvalve must be designed to withstand the extreme mechanical stresses of launch, to operate reliably over a wide temperature range and in the presence of ionizing radiation, and to operate reliably after a long time in storage or transit under the aforementioned temperature and radiation conditions. Additional requirements with regard to its specific function include an extremely low leak rate and immunity to



This **Normally Closed Diaphragm Valve** is opened by applying a voltage that causes the piezoelectric actuator to contract slightly. This cross section is not to scale: The fully developed prototype of this valve is expected to have a square footprint of 16 by 16 mm and a thickness of <3 mm.

disruption by small contaminant particles that may slip into the gaps between actuated valve sealing surfaces.

The design of this valve (see figure) is based partly on the designs of larger, commercially available diaphragm valves. Although the dimensions of this valve exceed the dimensions of most microelectromechanical devices, one is justified making this valve somewhat larger than a typical microvalve because the leak rate of a valve tends to decrease with increasing sealing area.

The valve begins as three separate parts: the base (which includes the seat), the diaphragm, and the actuator. The base, which is micromachined out of silicon wafer, contains the inlet and the outlet. The seat area on the inner (upper in the figure) surface of the base is textured with two sets of sealing rings: one centered on the inlet, the other centered on the outlet. The diaphragm, also micromachined out of a silicon wafer, features circular corrugations near its outer diameter and a central circular boss that covers both openings in the seat. The actuator consists of a stack of piezoelectric disks in a rigid housing machined out of a silicon wafer. A Ti/Pt/Au layer is evaporatively deposited on the faying surfaces of the three parts, then the parts are heated and pressed together to join the pieces with metal-to-metal diffusion bonds.

To apply a large sealing force on the two openings to ensure that the valve is normally closed, the piezoelectric stack is compressed into a slightly contracted condition during the bonding process. Application of a voltage across the stack causes the stack to contract further; this action lifts the diaphragm away from the seat, thereby creating a narrow channel between the inlet and outlet.

The geometry of the seal is expected to impart substantial immunity to disruption by small contaminant particles. The sealing rings are about 20 μm high and are numerous and closely spaced. Because they are many and dense, they still provide a large sealing area despite the valleys between them. At the same time, any small particles that are entrained in the fluid controlled by the valve and that come to rest in the seal area are expected to become trapped in the valleys between the rings, so that they will not disrupt the seal. Also, any single scratch that might occur would likely affect only a limited number of rings and thus be unlikely to create an open path from the inlet to the outlet.

This work was done by Indrani Chakraborty, William Tang, David Bame, and Tony Tang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

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Magnetostrictively Actuated Valves for Cryosurgical Probes

Probes could be made smaller and lighter, with better regulation of temperature.

NASA's Jet Propulsion Laboratory, Pasadena, California

In cryosurgical probes of a type now undergoing development, the flow of coolant (typically, liquid nitrogen) would be regulated by magnetostrictively actuated needle valves controlled by use of superconductive electromagnet coils. In comparison with cryosurgical probes now in use, the developmental probes would be smaller and lighter, and would afford better regulation of temperature. This concept is made feasible by two recent advances:

- Research at NASA's Jet Propulsion Laboratory has shown that reliable magnetostrictive cryogenic actuators can be manufactured relatively inexpensively by making actuator elements from commercial-grade magnetostrictive polycrystallike materials through a simple deformation process.
- Solenoids made from high-temperature superconductors, in the size and actuating-current ranges needed for cryosurgical probes, have recently become available in research quantities and are becoming commercially available.

Cryosurgical probes are used in some abdominal surgery and in prostate surgery to remove tumors. The basic concept in cryosurgery of the prostate is to place a probe in contact with the tumor, then use the probe to kill the tumor by freezing it. To freeze the affected prostate tissue to a fatal temperature without excessively damaging adjacent tissues, it is necessary to have a high cooling rate and to turn the cooling on and off at the proper times. Such thermal control is difficult to achieve in current cryosurgical probes and, as a result, adjacent tissues are damaged.

The main reason for the difficulty of thermal control in a current cryosurgical probe is that the valve that controls the flow of coolant is located near the coolant supply, and not in the probe. The approach taken in the present development effort is to exploit the inherent capability for miniaturization of a magnetostrictively actuated needle valve, placing the valve inside a cryosurgical probe within 1 or 2 cm of the tip. Thus, a small, rapidly controllable valve would be placed close to the location to which the cryogen is required to be delivered, making it possible to achieve better control over the timing and the rate of cooling. Moreover, the placement of the valve near the probe tip would make it possible to use narrower coolant-supply tubes with thinner insulation, so that the probe could be made smaller and lighter.

This work was done by Jennifer Dooley, Christian Lindensmith, and Robert Chave of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20575

Remote Sensing of Electric Fields in Clouds

Radar and radiometry would provide data on bulk orientation of ice crystals.

NASA's Jet Propulsion Laboratory, Pasadena, California

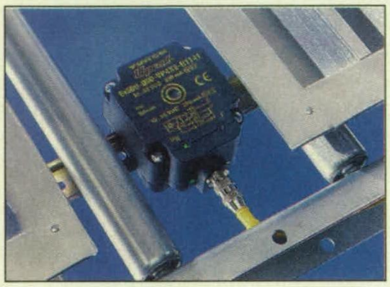
A proposed method for remote sensing of the electric field in a cloud that contains ice crystals would exploit the relationship between (1) the polarization-dependent radiometric or radar brightness of the cloud and (2) the average or bulk orientation of the crystals as affected by the electric field. The proposed method would complement other methods now used to measure natural electric fields in efforts to forecast lightning. A major advantage of the proposed method is that a few ground-based and/or airborne instruments could quickly survey a fairly large region of the sky.

In a nonelectrified cloud, the average orientation of ice crystals tends to be horizontal because it is aerodynamically stable. On the other hand, atmospheric electric fields, have vertical gradients that tend to electrically polarize the crystals, causing the orientation of their long axes to be aligned vertically. Hence the bulk orientation of ice crystals in a cloud is a balance between the electric and aerodynamic effects.

In the proposed method, one would observe a cloud by use of millimeter-wavelength radar, taking separate simultaneous measurements of the radar reflectivity in horizontal and vertical polarizations. Alternatively, one could measure the millimeter- or submillimeter-wavelength radiometric brightness temperature in both horizontal and vertical polarizations. The reason for doing so is that the bulk radar reflectivity or radiometric brightness temperature of the ice crystals depends on the scattering cross-section of the crystal. Since the long axis of the crystals has a greater cross-section than the short axis, the difference in radar reflectivity or atmospheric brightness at the two polarizations is sensitive to the bulk orientation of the crystals. In principle, it should be possible to invert the measurement data to retrieve information on the bulk orientation of the crystals and thus on the electric field.

This work was done by Steven J. Walter of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20895

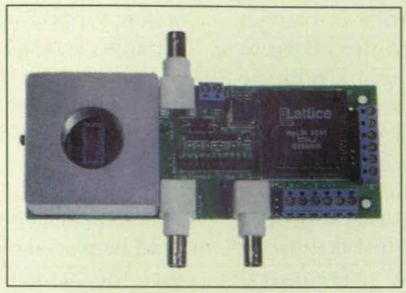
Special Coverage: Sensors



Turck, Minneapolis, MN, has introduced the Q80 embeddable **proximity sensor** with a 50-mm sensing range and dual diagnostic indicators, which provide a constant display of operating status. The dual diagnostic indication system consists of two sets of two LED indicators located on the face and front edge of the sensor. The Q80 can sense all types of metals at a single sensing range, including mild steel, stainless steel, copper, brass, and aluminum.

The sensor's Uprox technology provides weld-field immunity, eliminating false sensor triggering, and assuring operation in severe AC and DC weld fields. The sensor is available in 3-wire DC models with normally open outputs or normally closed outputs, a 4-wire DC model, and a 2-wire AC/DC model. The unit's one-piece housing is made of plastic PBT that meets NEMA standards.

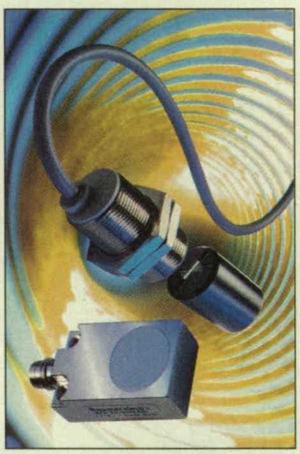
For More Information Circle No. 700



The SLIS series of **scanning linear image sensors** from Photon Vision Systems, Cortland, NY, is designed for ultra-high-speed scanning applications. The sensors use electronic shuttering, which allows simultaneous image capture and readout, and makes them suitable for applications that require a strobe light or to capture short-duration events. The sensors incorporate Active Column Sensor™ technology for ultra-low noise video.

Other features include 7 x 7 micron square pixels; resolutions of 2048, 4096, 6144, 8196, and higher; integrated full-frame electronic shuttering; integrated correlated double sampling; and on-chip integration of necessary timing and control circuitry. The sensors also include a 5 VDC power supply, several readout modes, and multiple ports via high-speed PVS-BUS video.

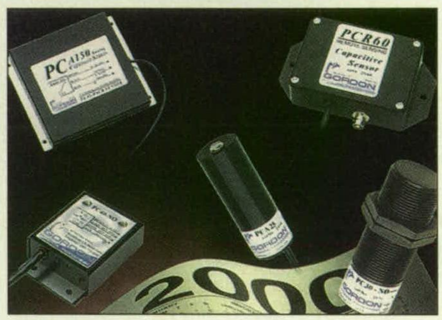
For More Information Circle No. 701



The MDRM **magnetic sensor** from Baumer Electric, Southington, CT, features analog output for use as a non-contact mechanical potentiometer in motion control applications. The sensor has a mechanical rotation range of ±80° and generates a linear voltage signal at its output. It is magnetically controlled by a small rotor positioned in front of the active sensing face and operating with a supply voltage of 5 VDC.

The sensor can be used in harsh environments with temperatures ranging from -20 to 85° C. It has no moving parts, is fully sealed, and is not affected by contaminants such as dust, water, oil, and cutting fluids. The sensor measures 18 mm in diameter and 30 mm long, making it suitable for restricted-space applications.

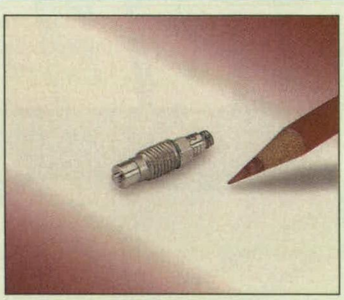
For More Information Circle No. 706



Gordon Products, Brookfield, CT, offers a line of **analog capacitive sensors** with analog outputs. The sensors are available in a variety of flat-pack and cylindrical housings, and are designed to accept expanded or remote sensing elements. They can monitor changes in density, composition, size, distance, or moisture content in applications such as monitoring liquid or solid fill levels, positioning of non-metallic objects, and composition-based object sorting.

The sensors can detect virtually any material. Sensing distances range from 0.25" to 4", depending upon the sensing element configuration, and the size, shape, and material properties of the target. The sensors operate on 10-30 VDC, and provide a 1-6 VDC output.

For More Information Circle No. 703



The Pressure and Force Sensors division of PCB Piezotronics, Depew, NY, has introduced the Series 105C ICP® **sub-miniature pressure sensors** for dynamic pressure measurement. The sensors feature all-welded, stainless steel construction with sensing diaphragms of less than one-tenth of an inch. The units are suitable for mounting in space-restricted locations. Sealed construction protects against contamination and permits use in submerged installations.

The sensors offer a variety of mechanical configurations, electrical connector options, and a choice of dynamic pressure ranges from 100 psi to 30k psi full-scale. Additional features include resolution to 0.005 psi, rise time of 2 microseconds, resonant frequency of 250 kHz, stable quartz sensing crystals, and built-in microelectronic circuitry.

For More Information Circle No. 705

Ono Sokki Technology, Addison, IL, has introduced the GS-503 **linear gauge sensor** for measuring dimensions, thickness, curvature, eccentricity, displacement, height, depth, flatness, variation, run-out, roundness, distortion, deflection, and load and pressure inspection. It uses linear glass scale technology and measures down to 0.0005" throughout a full 2" measuring range.

The sensor features a response speed of 39.4 feet per second and incorporates a carbon graphite spindle for measuring soft and compressible materials. The spindle also permits heavy lateral loading or side-impact force, and is resistant to extreme temperatures and rust. The sensor comes with a 6-foot signal cable that can be connected directly to an array of displays with various outputs for interfacing to a PC or datalogging system.

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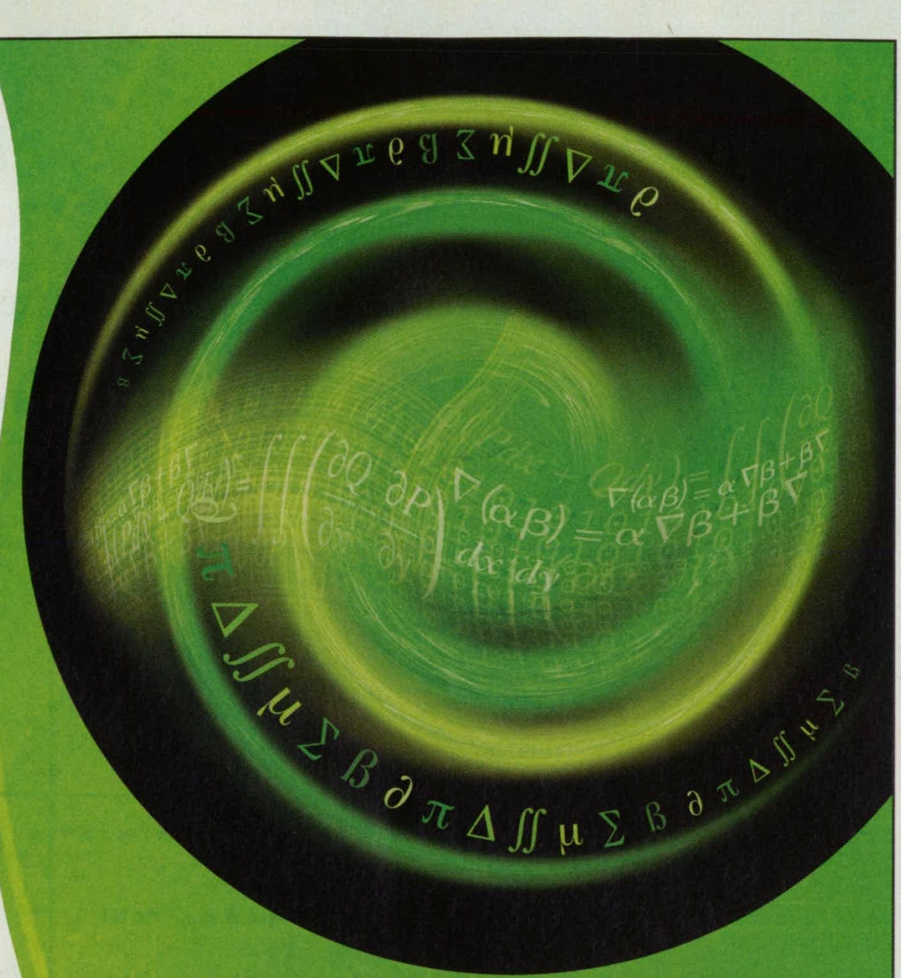

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Wireless-Communication Headset Subsystem To Enhance Signaling

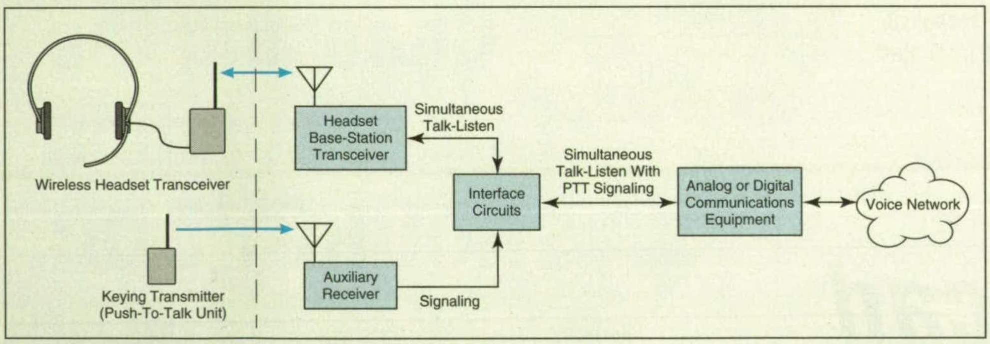
The user sends a push-to-talk signal through an auxiliary radio link.

John F. Kennedy Space Center, Florida

A special-purpose communications subsystem provides a push-to-talk signal to a communication system as if the individual was directly wired to the system. The subsystem also permits multiple wireless users to operate independently in the same environment. This interface operates in the 900-MHz industrial, scientific, and medical (ISM) frequency band and can be used with many different commercial off-the-shelf (COTS) wireless-communication headsets, without need to modify the headsets or the communications system in use.

COTS wireless-communication headsets operate continuously (transmit and receive), without the need for push-to-talk signaling, and are not designed to provide any special signaling like a push-to-talk signal or external "off hook" "on hook" signals. In the original application for which the present interface was developed, there is only a requirement for push-to-talk signaling to activate and deactivate users participating in launch operations via a COTS communication system. Similar communication systems are in use by Department of Defense agencies, law enforcement and public safety (including 911) call centers, other mission critical communications environments, and even commercial (telemarketing) call centers.

The interface has been prototyped, is in use for launch operations, and includes a push-to-talk unit carried by each headset wearer. This is a low-power auxiliary radio transmitter and is in addition to the radio transmitter of the headset. The interface could, however, be licensed for direct integration into COTS wireless headsets by the manufacturers, and could be expanded to perform a variety of specialized telephony functions, like DTMF (dual-tone multiple frequency) delivery, and on/off hook signals. The interface also includes an auxiliary radio receiver at the base station. When a wearer intends to transmit, the wearer keys the push-to-talk unit. Upon detecting the signal from the auxiliary transmitter, the auxiliary receiver at the base station generates a control signal equivalent to a conventional wired push-to-talk control signal. In the application that was prototyped, the control signal is one that commands the closure of a switch to turn on the audio circuits in the base station.



The **Keying Transmitter**, which is shown here separate from the transmitter of the headset, sends the push-to-talk signal to the auxiliary receiver at the base station.

This work was done by Marc Seibert of **Glenn Research Center** *and Anthony J. Culotta of Boeing for Kennedy Space Center. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-12052.

Power Amplifier With 9 to 13 dB of Gain From 65 to 146 GHz

Circuits like this one are needed for radar, imaging, scientific instrumentation, and communications.

NASA's Jet Propulsion Laboratory, Pasadena, California

A three-stage power amplifier has been developed, capable of operating without tuning, over a wide frequency band ranging well above 100 GHz. The original intended application of this circuit is as a driver amplifier for a passive frequency multiplier that would generate a local-oscillator signal in a submillimeter-wavelength heterodyne receiver. There is also a growing need for amplifier circuits like this one in other applications, including radar, imaging, scientific instrumentation, and communications.

This amplifier features four InP high-electron-mobility transistors in a grounded coplanar waveguide circuit with lumped-element interstage and shunt capacitors. The circuit also features a unique coplanar waveguide power-combining structure in the output stage.

The amplifier operates with a dc power of 400 mW and a 2-V drain bias on each transistor. As illustrated by the graph in

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• AC volts	100nV – 750V	100nV – 750V	100nV – 775V	100nV – 775V
• Ohms	100μΩ – 120MΩ	1μΩ – 120MΩ	1μΩ – 1GΩ	100nΩ – 1GΩ
• DC amps	10nA – 3A	1nA – 3A	10pA – 2.1A	10pA – 2.1A
• AC amps	1μA – 3A	1μA – 3A	100pA – 2.1A	100pA – 2.1A

For More Information Circle No. 544

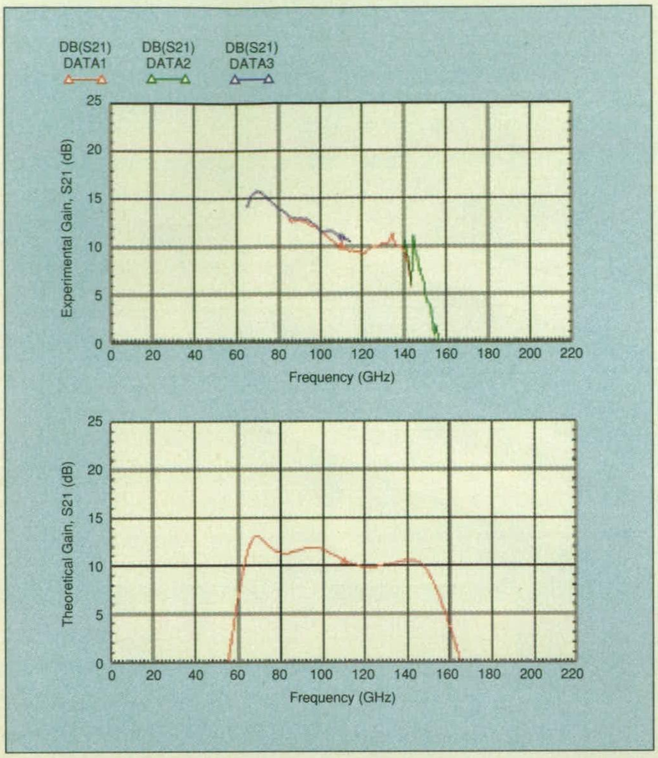

Figure 1. This **Three-Stage Transistor Amplifier** with coplanar waveguide interconnections exhibits at least 9 dB of gain over 80 GHz of bandwidth and spans three waveguide bands. Experimental (upper graph) and theoretical (lower graph) amplifier gains are shown as a function of frequency. The experimental data were obtained by measuring the amplifier gain in three different waveguide bands: 65 to 115 GHz (DATA3), 85 to 140 GHz (DATA1), and 140 to 220 GHz (DATA2).

Figure 1, the amplifier exhibits 9 to 13 dB of gain over the frequency range from 65 to 146 GHz, and spans three waveguide bands. The output RF (radio-frequency) power was measured to be 25 to 40 mW from 106 to 140 GHz. The chip photograph is shown in Figure 2.

This work was done by Lorene Samoska and Sander Weinreb of Caltech, Yoke Choy Leong of UMass, and Mehran Matloubian of HRL for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
NPO-20880

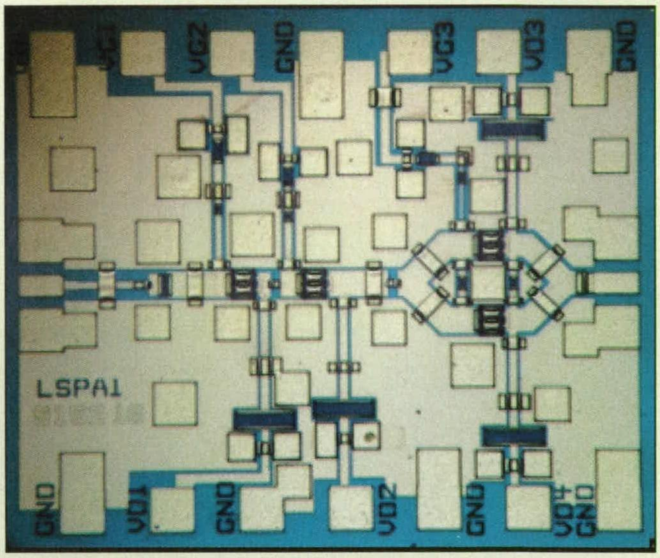

Figure 2. The **InP Wide-Band Amplifier** is shown in this chip photograph.

Humidity Interlock for Protecting a Cooled Laser Crystal

A thermoelectric cooler is disabled when the humidity exceeds a preset level.

NASA's Jet Propulsion Laboratory, Pasadena, California

A humidity interlock has been developed to prevent damage that could be caused by condensation of water on a delicate and expensive laser crystal that must be maintained at a temperature below ambient during operation. The humidity interlock is installed in conjunction with the laser temperature controller system. Whenever the humidity inside the laser housing rises beyond a safe level, the humidity interlock turns off power to a thermoelectric cooler on which the laser crystal is mounted.

The humidity interlock (see figure) consists of (1) a small, inexpensive, commercially available humidity sensor placed inside the laser housing, and (2) a control circuit. The sensor generates a voltage proportional to the local humidity. The sensor output is fed into a conditioning amplifier for conversion into a voltage indicative of the percent relative humidity (RH%). The RH% voltage is compared with a voltage representative of low RH% that is considered acceptable for safe operation of the laser and is designated the trip point. A technician can adjust the trip point by use of a potentiometer in the circuit.

When the RH% inside the housing is below the trip point, a comparator in the circuit activates a relay that closes a switch

through which current flows to the thermoelectric cooler. When the RH% is above the trip point, the relay switch remains open, disabling the cooler.

Included in the interlock circuit is a two-color light-emitting diode (LED) that shines red or green, depending on whether the humidity is above or below the trip point, respectively. There is also a front-panel display device that indicates either the RH% or the trip point. The circuit includes an override switch that enables the cooler to operate when the humidity exceeds the trip point.

This work was done by Carlos Esproles of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
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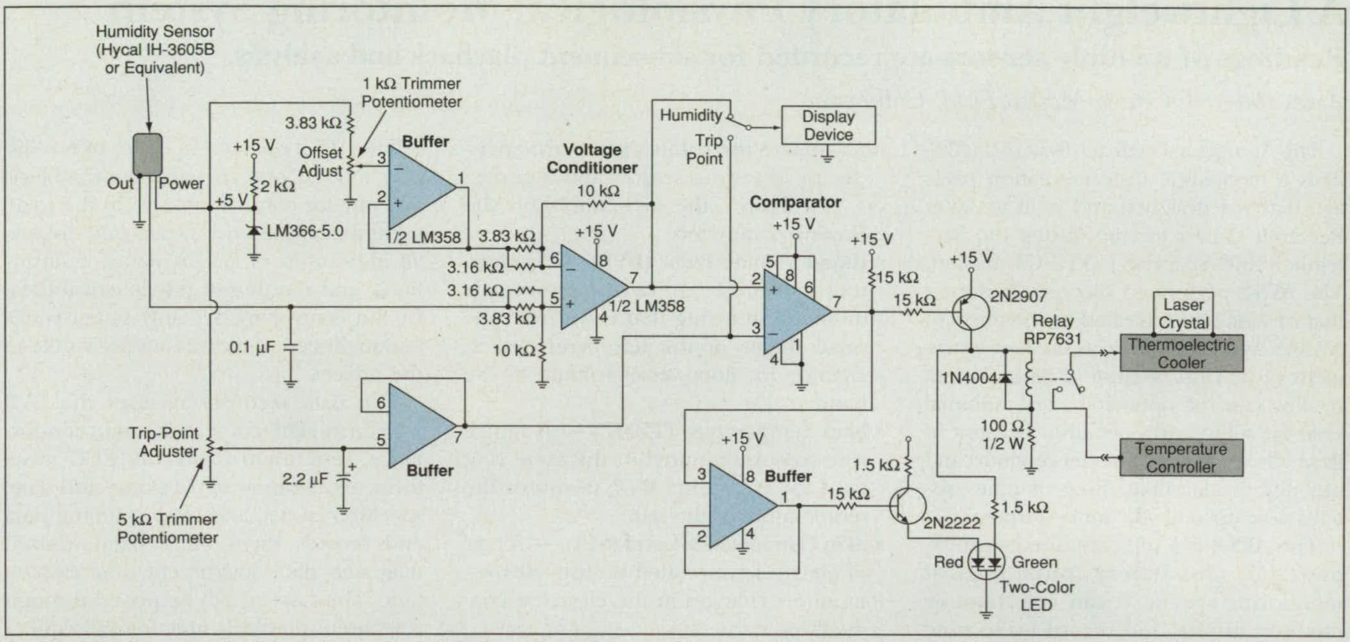


The **Humidity Interlock Circuit** includes a relay switch through which power flows to a thermoelectric cooler. The switch is opened when the relative humidity exceeds a trip point.

A Lightweight Ambulatory Physiological Monitoring System

Readings of multiple sensors are recorded for subsequent playback and analysis.

Ames Research Center, Moffett Field, California

The Autogenic-Feedback System-2 (AFS-2) is a biomedical instrumentation package that was designed and built at Ames Research Center for use during the September 1992 Spacelab-J (STS-47) mission. The AFS-2 performed successfully during that mission and was rated by members of NASA's Astronaut Office as the best instrument of its kind because of its high data quality, ease of operation, and minimal time for setup and operation. Because of its small size, this system offers comfort and mobility greater than those of other systems developed for the same purpose.

The AFS-2 is a self-contained, battery-powered, ambulatory, physiological monitoring system. It can continuously monitor, display, and record up to nine channels of physiological data for up to twelve hours on a single change of batteries. Sensors and transducers, placed in various locations on the subject (e.g., an astronaut), monitor the physiological signals. A wrist display unit displays the subject's physiological parameters in numerical form. The AFS-2 records all acquired information on a data instrumentation tape by use of a modified nine-channel frequency-modulation data recorder. Researchers can thereafter play back the tape to extract the data and analyze the subject's performance.

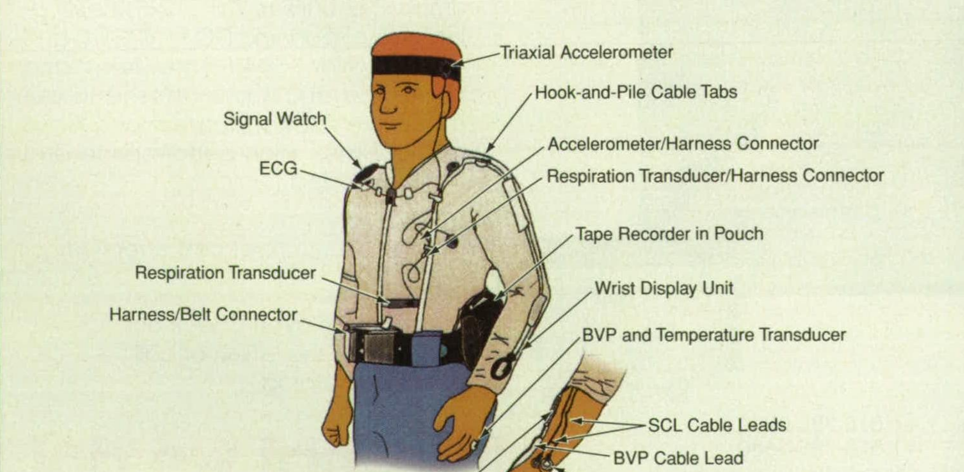
By use of various sensors and transducers (see figure), the AFS-2 monitors the following parameters:

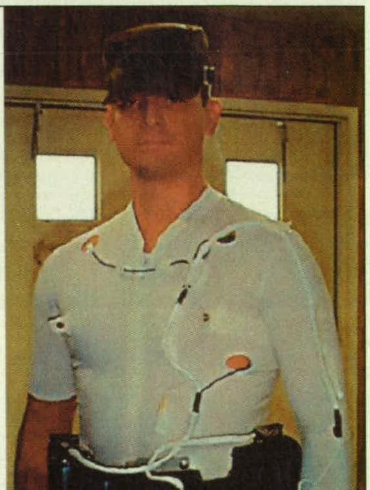
- **Blood Volume Pulse (BVP)** — A miniature infrared emitter-detector pair mounted in a ring that is worn on the small finger of the left hand detects changes in blood-vessel volume in the hand.
- **Skin Temperature (TEMP)** — A miniature sensor, mounted in the same ring used for measuring BVP, measures the temperature of the skin.
- **Skin Conductance Level (SCL)** — A pair of electrodes mounted on the left wrist monitors changes in the electrical conductivity of the skin.
- **Respiration (RESP)** — A thin piezoelectric film sandwiched between two flexible rubber housings and strapped across the diaphragm measures both the range and frequency of respiratory cycles.
- **Electrocardiography (ECG)** — Three standard electrodes placed at the AvR, AvL, and AvF chest nodes monitor the electrical impulses of the heart.
- **Acceleration (ACCEL)** — An accelerometer attached to a flexible cotton headband measures the motion of the subject's head along three axes.

The AFS-2 operates in either of two display modes: one for treatment subjects and one for control subjects. In the treatment mode, the wrist display unit displays all indications of system status, malfunctions, and monitored physiological data. In the control mode, only system-status and malfunction indications are visible to the subject.

The data recorder receives the BVP waveform, skin temperature, skin conductance, respiration waveform, ECG waveform, acceleration signals, time and date, specified events, and session timing data and records them on a standard-sized magnetic data instrumentation cassette tape. The cassette can be played through a separate playback unit for subsequent analysis at speeds up to 32 times the speed at which the data were recorded.

The AFS-2 is divided into three general subsystems: the wrist display unit, the belt assembly, and the garment and cable harness assembly. The wrist display unit, fastened to the left sleeve of the AFS-2 garment, includes a small liquid-crystal display device that presents physiological and system-status information to the user. The belt assembly is worn around the waist and over any clothing. The belt assembly comprises belt electronic circuitry





A **Human Subject Is Instrumented With Sensors** to measure multiple physiological parameters simultaneously.

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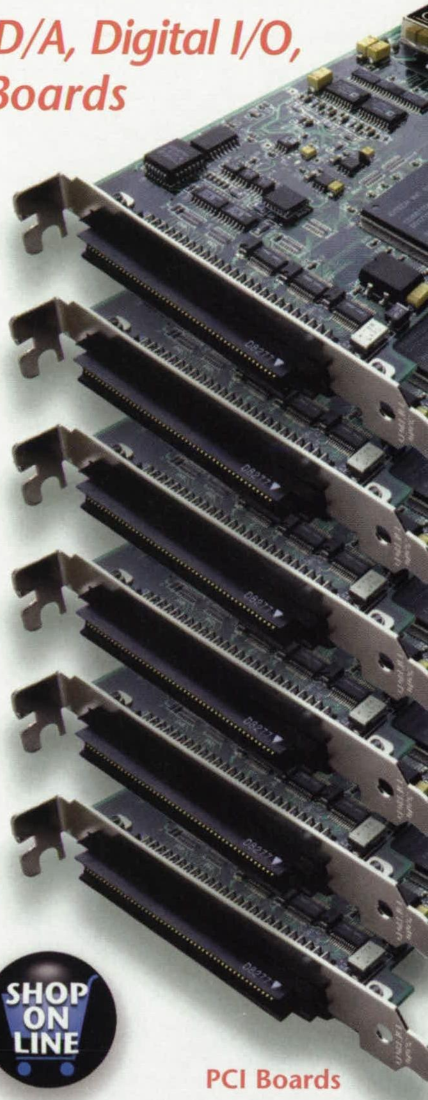

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Digital I/O	40	40	40	40	40	–
Frequency/pulse I/O	6	6	6	6	6	–
Signal conditioning options	27	27	27	5	5	–
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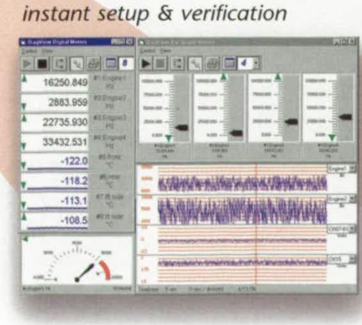

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(signal-conditioning amplifiers, an analog-to-digital converter, and a microcontroller), a battery pack, the data recorder, and an interface cable. A modular design distributes the weight of the belt assembly evenly around the waist. The components of the system are interconnected through easily mated and demated connectors; this design feature minimizes the time needed for donning the AFS-2. The battery pack supplies power to all subsystems, including the data recorder. The battery pack features a clip-on design for fast and easy replacement of exhausted batteries. The AFS-2 garment assembly is worn on the upper body and covers the torso and left arm. The garment assembly comprises the garment, the cable harness, the respiration transducer, the accelerometer, and the ring transducer.

This work was done by Patricia Cowings, Scott Jensen, Dave Bergner, and William Toscano of **Ames Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Test and Measurement category.*

This invention has been patented by NASA (U.S. Patent No. 5,694,939). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14048-1.

Improvements in a Lightning-Measuring Instrument

John F. Kennedy Space Center, Florida

Some improvements have been made in the instrument described in "Instrument Records Magnetic Fields Generated by Lightning" (KSC-11769) *NASA Tech Briefs*, Vol. 19, No. 4 (April 1995), page 38. To conserve battery energy, the instrument was made to record the output of only one of three mutually orthogonal loop antennas and to operate in a "sleep" mode except when "awakened" by a lightning strike. Unfortunately, with this energy-conserving strategy, sometimes even a nearby lightning strike could fail to wake the system up on time to record the first strike. The improvements, directed toward overcoming this trigger deficiency, include (1) replacing the "sleep" mode with a mode in which the signals from all three antennas are sampled sequentially at a reduced rate and multiplexed onto one channel and (2) modifying the triggering scheme and the "awake" mode so that once a signal in at least one channel exceeds the trigger threshold, the signals from all three antennas are sampled at a high rate simultaneously on three digitizing channels for 100 μs. Signal samples acquired at the reduced rate for the past 100 μs at the moment of triggering are stored, along with the samples acquired at the full rate for the 100 μs following the moment of triggering.

This work was done by Pedro J. Medelius of Dynacs Engineering, Inc., for **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Test and Measurement category. KSC-12088*

For More Information Circle No. 418

Broad-Band, Noninvasive Radio-Frequency Current Probe

This circuit responds in approximately constant proportion to current over a wide frequency range.

Goddard Space Flight Center, Greenbelt, Maryland

An instrument that noninvasively measures alternating current over a broad frequency band (typically from about 0.3 to about 110 MHz) has been invented. This instrument could be especially useful for assessing radio-frequency hazards by measuring currents in various parts of humans or personnel exposed to radio-frequency electromagnetic fields.

The instrument includes a magnetic pickup coil connected to an active circuit that measures the current induced in the coil by the magnetic field of the current that one seeks to measure. The pickup coil is of a type known in the art as a Rogowsky coil or Rogowsky transformer. As such, the coil is essentially the secondary winding of a transformer with a toroidal core that is placed around the human limb or other object that carries the current that one seeks to measure. The current-carrying object acts, in effect, as the primary winding of the transformer. To avoid the weight, cost, and nonlinearity of a ferrous core, and to minimize the effect of the perturbation of the current to be measured, the coil in this circuit is wound on a nonferrous core.

The active circuit used to measure the current induced in the coil is similar to active-antenna circuits developed previously at NASA for measuring the magnetic components of electromagnetic fields at frequencies up to a few megahertz. The active circuit includes an operational amplifier. The virtual ground at the input terminals of this amplifier is used to present a low impedance to the coil, thereby making the series resistance of the coil circuit much less than the inductive reactance of the coil, even at the low end of the frequency range.

By basic principles of electromagnetism, the voltage induced in the coil is proportional to the frequency and to the current that one seeks to measure, while the inductive reactance of the coil is proportional to the frequency. The current in the coil, which is the current sampled by the amplifier, equals the ratio between the voltage induced in the coil and the total impedance of the coil circuit. Hence, at all frequencies for which the inductive reactance is the dominant component of the impedance of the coil, the coil current sampled by the active circuit is proportional to the current that one seeks to measure.

This work was done by John F. Sutton of **Goddard Space Flight Center** *and Mark J. Hagmann of Florida International University. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Test and Measurement category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13985.

Web-Based Technology Distributes Lean Models

TECH BRIEFS MODEL AND SIMULATION EXCHANGE

Users can share models while protecting intellectual property.

Beam Technologies, Waltham, MA

Everybody creates models. These models are used to understand how products will hold up to the stresses, use, and abuse of real-world deployment; analyze the impact of design decisions on cost; simulate interactions; or evaluate numerous other metrics. Unfortunately, because of the variety of software tools available and the cost of acquiring them, models may not be compatible with the software used by customers and suppliers. Sharing models creates the fear of exposing intellectual property, especially if those sharing the models can understand the source code.

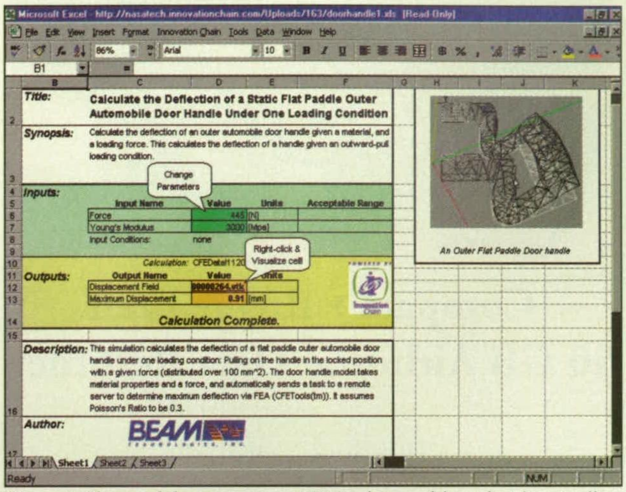


Figure 1. The model appears as a MS-Excel spreadsheet but is actually a control panel to calculations running on remote servers.

Using an MS-Excel spreadsheet as a "control panel," one can build lean models that allow partners to use a firm's models while, at the same time, preventing them from seeing proprietary calculations. Proper functioning of the "control panel" requires that the user load a Plug-In to Excel. With the Plug-In loaded, the user downloads the control-panel spreadsheet to their desktop and modifies the model's inputs in MS-Excel. The changes prod the Plug-in to transfer the input values to a remote engineering server that launches the model with the user's input values. When the simulation is complete, the results are extracted from the model and returned to the spreadsheet. Since the user never downloads the actual model, they cannot extract intellectual property.

Consider, for example, the manufacturer of car door handles who might want to evaluate numerous materials for suitability. By creating a lean model (Figure 1) and making it available to a range of material suppliers, the manufacturer can determine the effectiveness of a range of materials without sharing the specifics of their door handle model. This model (http://nasatech.innovationchain.com/solution.asp?SN=163), which can be used by registering and installing the MS-Excel Plug-In, uses as Inputs the force in Newtons on the door handle and Young's Modulus (a key material property that indicates how a material responds to stress-strain). As Outputs, the model produces the maximum displacement of the material in millimeters and a visualization of the displacement field. The displacement field can be viewed by right-clicking on the appropriate cell and selecting "Visualize." Because the model is locked and protected, the user can see results but none of the calculations.

For more information on creating or distributing lean models, contact Beam Technologies, 404 Wyman St, Suite 355, Waltham, MA 02451; (781) 890-509; or visit the web site at www.beamtech.com.

Software Guides Aeroelastic-Systems Design

TECH BRIEFS MODEL AND SIMULATION EXCHANGE

The program dramatically slashes time and cost by eliminating debilitating limitations of current aeroelasticity prediction methods.

Beam Technologies, Inc., Waltham, MA

Accurately and efficiently predicting the unsteady dynamics of coupled, fluid-structure systems significantly reduces the cost of designing, testing, and maintaining fixed-wing aircraft, rotorcraft, and turbomachinery. It also improves safety. Organizations can realize substantial savings by understanding these dynamics, because aeroelastic loading increases fatigue cycling and reduces vehicle operating life. Further savings come from designing for lower fleet sustainment costs without incurring additional flight-test expenses. For example, aircraft with weapons stores require certification flight tests for each stores configuration. Replacing flight tests with computational simulations could significantly lower acquisition costs.

Accurate methods of predicting aeroelasticity are also essential in non-aerospace applications where fluid-structure interaction relates to efficient product operation and such important issues as noise control. Engineers can use fluid-structure interaction models to design products that accommodate fluid flow and moving boundaries during operations. Examples range from ink-jet printers with vibrating-diaphragm injection systems to nuclear reactors with flexible fuel rods suspended in high-speed coolant flows.

The problem of fluid-structure interaction is characterized by two dynamic

subsystems — fluid and structure — each with its own inertia, stiffness, and damping. The forces that each exerts on the other couple the subsystems. Engineers are concerned with the temporal dynamics of this coupled system. In the case of a lifting surface, the engineer must determine system stability over a range of such operating conditions as Mach number, altitude, and angle of attack.

Inherent difficulties in the problem leave the engineer with two imperfect ways of modeling the coupled system. The difficulties center on the forcing terms that couple the two systems and how the engineer characterizes and then introduces the terms into the equations that govern the fluid and structure. One modeling approach estimates structural deflection growth rates using linearized approximations of the aerodynamic loads. This method follows the tack of modern stability analysis — with approximations to viscous fluid force that limit the scope of application. A second method iteratively marches the model of the fluid and the model of the structure forward in time. This "brute force" approach demands computational resources that can easily become prohibitively expensive.

AeroMechanics is a patent-pending program (http://nasatech.innovationchain.com/solution.asp?SN=186) that predicts and ultimately lets one control the unsteady dynamics of aeroelastic systems. Through a general, curvilinear coordinate transformation, the program achieves exact coupling between the fluid and structure without compromising the effects of viscosity, separation, shocks, and shock-boundary layer interaction. The computational formulation enables a comprehensive approach to the analysis of system dynamics: capturing weak nonlinearities in an eigensystem formulation, strong nonlinearities using the full nonlinear system and dynamic systems methods, and detailed flow dynamics in time-marched simulations of the fully-coupled model.

The eigensystem predicts the stability of the physical system in the presence of weak nonlinearities. The computed eigenvalue of each variable determines its time-dependent behavior — growth, decay, oscillation, oscillatory growth, or oscillatory decay. Therefore, the model can predict the dynamic behavior of the fully-coupled system without iterative time marching, re-meshing, and with no limiting approximations. Time-marched simulations require many CPU hours; even smaller problems like flow over a two-dimensional airfoil require 15 or more CPU hours to predict system dynamics from an initial state to equilibrium. Within minutes, AeroMechanics accurately predicts system stability, enabling a complete exploration of the design early in the process. The computational model has been validated by comparing data from simulations with known, exact solutions and with independent computational data. Maximum relative differences between known, exact solutions and data from the model are consistently small — less than one percent.

This work was done by H. A. Carlson and R. E. Miller of Beam Technologies, Inc. for the Aeroelasticity Branch at **NASA's Langley Research Center**. *For more information, contact Beam Technologies, 404 Wyman St., Suite 355, Waltham, MA 02451; (781) 890-509; or visit the web site at www.tekspk.com/beam/index.html.*

Postprocessing Software for Micromechanics Analysis Code

John H. Glenn Research Center, Cleveland, Ohio

The Micromechanics Analysis Code Post-Processing (MACPOST) computer program is designed primarily to serve as an improved means of processing the output of the Micromechanics Analysis Code With Generalized Method of Cells (MAC/GMC) computer program. [MAC/GMC was described in "Comprehensive Micromechanics-Analysis Code (MAC/GMC)" (LEW-16870) *NASA Tech Briefs*, Vol. 24, No. 6 (June 2000), page 38. To recapitulate MAC/GMC is a comprehensive, user-friendly, efficient program that predicts the elastic and inelastic thermomechanical responses of continuous and discontinuous composite-material structures that have arbitrary internal microstructures and reinforcement shapes and are subjected to complex thermomechanical load histories.]

MACPOST operates within MSC/PATRAN — a commercial package of preprocessing and postprocessing software. MACPOST is written in the Patran Command Language (PCL), which is the programming language embedded in PATRAN. MACPOST establishes a direct link between the analysis capabilities of MAC/GMC and the postprocessing capabilities of MSC/PATRAN. MACPOST enables the graphical display of results of a MAC/GMC analysis in the following ways:

- Contour plots of spatially and/or temporally localized results can be generated. For example, such a plot could indicate the spatial variation of stress or strain over a composite-material unit cell (that is, on a microscopic scale) at a specific time step of the analysis. Alternatively, one can require that local results be displayed at a point where a specified stress or strain on the macroscopic (average or global) level is indicated by the analysis.
- The user can require the generation of two-dimensional (X-Y) plots of such quantities as temporal variations of stress, strain, and/or other specified quantities at the macroscopic or microscopic level (even within individual subcells of a composite-material unit cell).

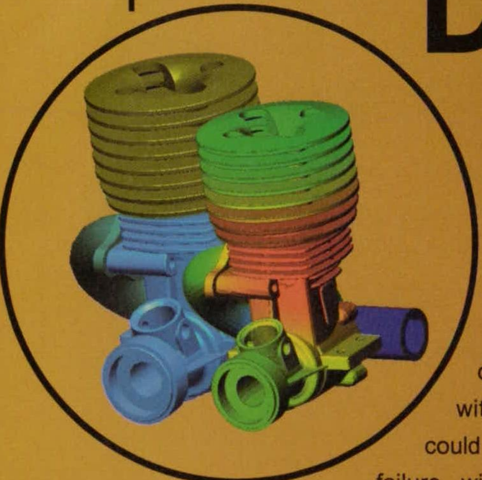
The user provides input through a series of menus and forms. MACPOST checks for input errors. From the user input, MACPOST automatically carries out the MSC/PATRAN commands needed to generate the desired graphical displays. As a result, a user who is familiar with MAC/GMC but has only minimal knowledge of MSC/PATRAN can obtain useful results.

MACPOST enables the user to examine the MAC/GMC output more thoroughly. For example, by examining X-Y plots of results on the macroscopic scale, the user can identify spatial and/or temporal regions of particular interest; for example, the time when a stress-vs.-strain plot becomes nonlinear. Through the contour-plot option, the user can then examine graphically the variation of such quantities such as effective stress over the unit cell at the point of interest. By examining the contour plots, the user can determine what microscopic effects (for example, matrix-material stresses reaching the yield point) caused the trend observed in the macroscopic results.

This program was written by Robert K. Goldberg and Steven M. Arnold of **Glenn Research Center** *and Brett A. Bednarcyk of Ohio Aerospace Institute. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

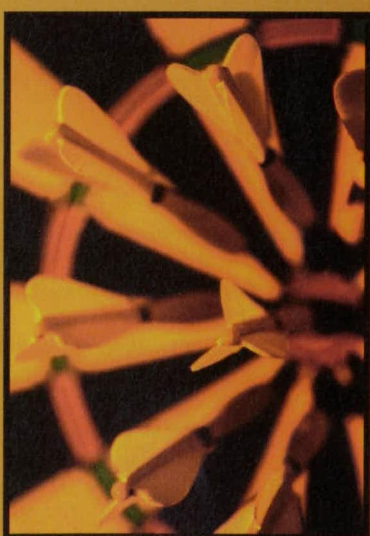
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16945.

Don't Take Chances with your Designs



Will it overheat? Will the stresses be too high? Will it break? If you are designing your models without using analysis, you could be risking a potential part failure - without even realizing it. Don't take unnecessary chances with your design. Use COSMOS/ throughout the design cycle to help identify potential problems before it's too late.

No matter what you are designing, from the most complex assembly to the simplest part, COSMOS/ can improve the quality and performance of your models. COSMOS/ offers a full range of powerful design analysis tools, including dynamic and nonlinear analysis, optimization, motion simulation, fluid dynamics, and electromagnetics. Created with non-specialists in mind, COSMOS/ combines affordability, ease-of-use and high-end features with built-in accuracy tools and blindingly fast solvers.



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Better Packaging for Miniature Immersible Diagnostic Systems

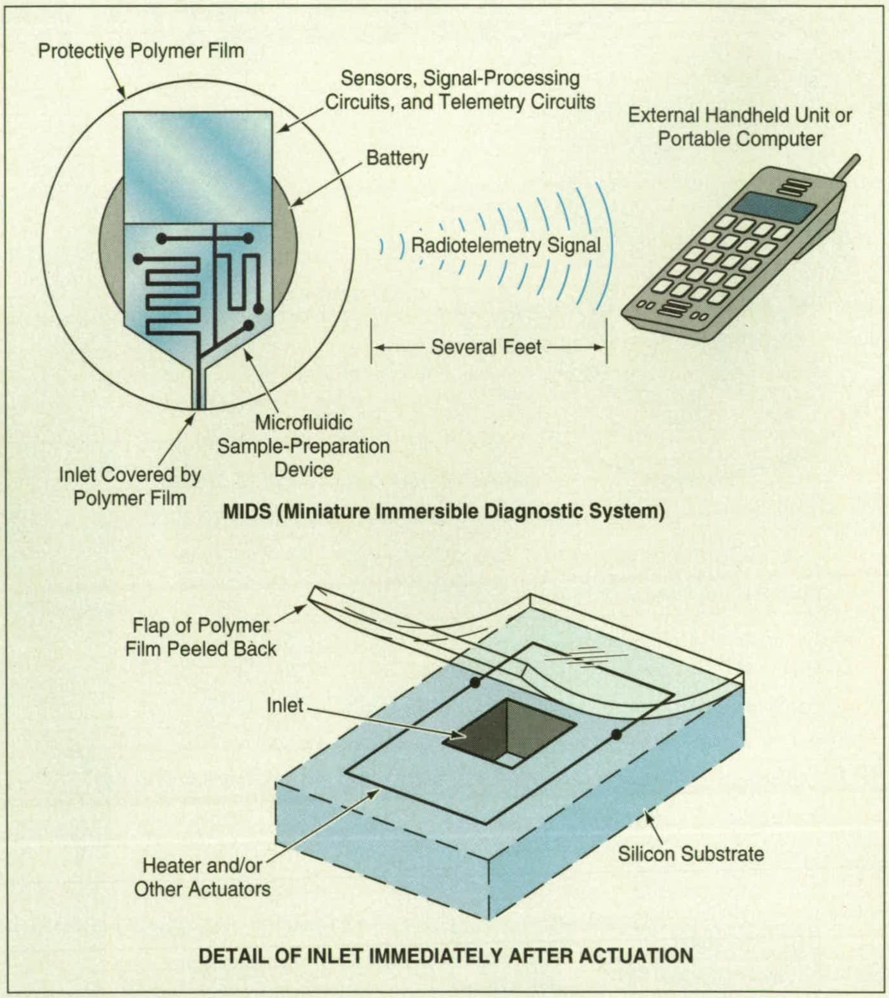
Protective films could be broken on command to expose sensors.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of packaging now under development would afford improved protection and functionality for miniature immersible diagnostic systems (MIDS). The method involves covering a MIDS with a thin hermetic film that, if necessary, can be broken on command to expose one or more sensor(s) in the MIDS to the environment to be sensed.

MIDS are members of a growing class of advanced microelectromechanical systems (MEMS) that have been and are being developed for use primarily as biosensors, including (but not limited to) chemical and temperature. Conceptually, MIDS are designed to be fully immersed in water to sense water-borne toxicity or biohazards, or in bodily fluids (e.g., in the gastrointestinal tract) to gather information on patients' health. In addition, the basic MIDS concept will likely be extended to the development of miniature immersible systems for delivering drugs and/or acquiring liquid samples.

Some MIDS are designed to be permanently encapsulated for protection, and yet able to function without direct contact between their environments and delicate sensor components; a body-temperature sensor is an example of this kind of MIDS. Other MIDS (e.g., those for detecting water-borne biohazards) must be at least partly immersed in order to function; therefore, their operational lifetimes can be limited and the onset of operation cannot be delayed. The present developmental method would make it possible to delay the onset of operation; in other words, a delicate MIDS could be kept sealed against hostile surroundings until commanded to expose itself to the surroundings to perform its sensory function.



One or More Actuator(s) Around the Inlet would, on command, disrupt the polymer film that surrounds the MIDS to allow ambient liquid to enter the inlet.

The figure schematically illustrates a conceptual MIDS packaged according to the present developmental method. The MIDS would include a microfluidic sample-preparation device that would acquire one or more sample(s) of the ambient liquid to one or more sensor(s). The sensor outputs would be processed and telemetered to an external hand-held receiving unit or portable computer. The entire exterior surface of the MIDS would be protected by a thin polymer film. The portion of the film covering the inlet to the sample-preparation device would be delineated by an underlying electric-heating wire or other actuator. Upon command, the actuator would melt, tear, and/or otherwise disrupt the film to allow the surrounding liquid to enter the inlet.

Thus far, films of an amorphous fluoropolymer with thicknesses of 0.8±0.2 μm have been applied to silicon substrates and analyzed with respect to adhesion, protective properties, amenability to patterning, and amenability to disruption on command. Experiments have shown that disruption on command is more difficult than had been anticipated. It may be possible to overcome this difficulty through a combination of patterning and increasing actuation force.

This work was done by Gisela Lin, Kevin King, and H. L. Kim of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*
NPO-20954

Lightweight Composite-Material Tanks for Cryogenic Liquids

Liner and composite wrap materials can be chosen to suit specific applications.

Marshall Space Flight Center, Alabama

A lightweight composite-material tank suitable for the storage and transport of liquid oxygen and other cryogenic liquids has been developed. The tank includes a metallic liner compatible with liquid oxygen, a graphite/ epoxy overwrap, an insulating layer of lightweight polyurethane foam, an aromatic polyamide/epoxy overwrap for resistance to abrasion and impact, and one or two lightweight fittings or bosses. Tanks of this type have been made with diameters ranging from 6 to 36 in. (15 to 91 cm) and lengths ranging from 1 to 4 ft (30 to 122 cm).

Fabrication of such a tank begins with the formation of a eutectic-salt mandrel in the desired size and shape of the interior tank volume. The eutectic salt must be chosen so that the mandrel will withstand the temperature of curing at a subsequent stage of fabrication described below.

The salt mandrel is fitted with two lightweight bosses as follows: First, a thin-walled aluminum boss is machined and plated with a thin coat of nickel. Next, a graphite/epoxy composite boss is cast and fit over the aluminum boss. The salt mandrel is sealed and later coated with nickel by electroforming. The nickel layer bonds with the boss end fittings and, together with the end fittings, encloses and defines the interior tank volume; that is, the nickel layer becomes the metallic tank liner. The thickness of the nickel layer is typically 5 mils (≈0.13 mm), but the layer can easily be deposited to a different thickness as needed for a specific application.

Optionally, the bosses could be machined from pure aluminum and aluminum or poly(tetrafluoroethylene) could be used as the liner material in place of nickel. An aluminum liner could be deposited by wire arc spraying or vacuum deposition; a poly(tetrafluoroethylene) liner could be deposited by flame spraying or powder coating. An aluminum or poly(tetrafluoroethylene) liner is preferable to a nickel one if the fluid to be contained is highly concentrated hydrogen peroxide.

The metal-coated mandrel is wrapped with multiple layers of graphite fibers impregnated with an epoxy resin that, preferably, is compatible with liquid oxygen. In an application in which there is a risk of corrosion at the interface between the metallic liner and the graphite/epoxy, a fine layer of glass/epoxy could be wrapped around the metallic liner first. The overwrap structure can be filament-wound, manually laid with fabric, or a combination of both. The wrapped workpiece is cured in an autoclave or an oven, typically at a temperature of ≈100 °F (≈38 °C) and pressure of ≈100 psi (≈689 kPa). After the cure, the salt mandrel can be washed out from within by use of water; alternatively, the mandrel can be left in place temporarily.

The polyurethane foam is sprayed over the workpiece, then machined to the desired wall thickness and profile. The aromatic polyamide/epoxy composite is wrapped over the foam, then cured. A very thin rubberized coat can also be sprayed or brushed on the cured aromatic polyamide/epoxy overwrap for additional protection against abrasion.

This work was done by Thomas K. DeLay of **Marshall Space Flight Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at (256) 544-5226 or sammy.nabors@msfc.nasa.gov. Refer to MFS-31379.

Improved Formulation and Deposition of Ablative Insulation

This formulation performs better and is not harmful to the environment.

Marshall Space Flight Center, Alabama

The term "Marshall Convergent Coating-1" ("MCC-1") denotes an improved formulation and a concomitantly improved method of spray deposition of a cork-and-glass-filled epoxy ablative thermal-insulation material. MCC-1 has been used on the space shuttle solid rocket booster and on some Air Force and commercial rockets, and at least one aircraft manufacturer has expressed interest in commercial applications of MCC-1.

MCC-1 was developed to replace an older formulation and spray deposition process that entailed four major disadvantages: (1) hazardous solvents were used; (2) the older process was a batch process and, as such, was limited by a pot life; (3) it was necessary to sand each substrate prior to spray deposition of the material; and (4) the material tended to come off during flight and/or splashdown.

In comparison with the older formulation and process, MCC-1 is environmentally friendly because it does not involve the use of any solvents. The MCC-1 process is a continuous (albeit interruptible) rather than a batch process: the ingredients are mixed only during spraying for immediate application on demand; consequently, the process can be started or stopped at will and pot life is no longer an issue.

The system of equipment used in MCC-1 for the space shuttle includes the following:

- Pots for holding and subsystems for delivering the wet and dry ingredients, which are the epoxy resin, epoxy catalyst, ground cork, and micron-size glass spheres;
- A Convergent Spray Technology (CST™) nozzle, which is designed specifically for use in this process;
- Process-control and data-acquisition equipment;
- A spray-cell with environmental control system;
- A robot that moves the CST™ nozzle; and
- A turntable on which the substrate to be coated is placed.

The epoxy adhesive is atomized in a flow of air and sprayed by use of the nozzle. The ground cork and glass microspheres are delivered via an eductor air line, mixed in a cyclonic mixer, then injected into the adhesive spray plume outside the nozzle. The composition of the sprayed and deposited material is controlled by regulating the rates of flow of the individual ingredients. The pattern of deposition of the material on the substrate is controlled by regulating the trajectory of the robot and the speed of the turntable. Once the spraying process has been completed, the deposited material is cured by gradually heating it to a temperature between 112 and 200 °F (between 44 and 93 °C) and holding it at that temperature for at least 9 hours.

In comparison with the older batch process, the mix-and-spray-on-demand MCC-1 process generates significantly less waste and thus necessitates less cleanup. Unlike in the older process, it is not necessary to sand the substrate prior to spraying. The flatwise tensile strength of the MCC-1 deposited material is superior to that of the material deposited by the older process. In addition, thus far, little or no falloff of MCC-1 material in flight or splashdown has been observed.

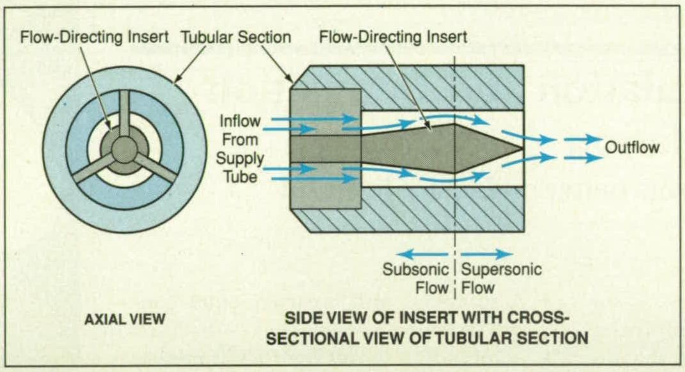
This work was done by Carl N. Lester of **Marshall Space Flight Center** *and Samir V. Patel formerly of USBI. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category. MFS-31295*

Flow-Concentrating Supersonic Gas/Liquid Nozzles

In comparison with prior supersonic cleaning nozzles, these are more effective.

John F. Kennedy Space Center, Florida

Flow-concentrating supersonic gas/liquid nozzles have been invented for use in cleaning and in verifying the cleanliness of tanks, pipes, tubes, machine parts, and structures. The overall function of these nozzles is to generate concentrated two-phase flows, the mechanical action of which is highly effective in cleaning surfaces.



The **Two-Phase Fluid** flowing in from the supply tube becomes compressed between the flow-directing insert and the inner surface of the tubular section. After reaching maximum compression at the outermost diameter of the insert, the fluid expands to supersonic speed and converges upon itself, forming an intense jet that is highly effective for cleaning.

Previously, cleaning processes of the type to which these nozzles apply have involved flushing with solvents, spraying liquids at high pressure through nozzles, and the use of supersonic DeLaval nozzles. Solvent flushes use large volumes of chemicals to dissolve contaminants. High-pressure liquid sprays consume smaller quantities of solvents than solvent flushes, but the volumes are still substantial. Cleaning processes that involve supersonic DeLaval nozzles are the best of this type for minimum solvent usage, but the basic design and principle of operation of DeLaval nozzles leave room for improvement.

A nozzle of the present type includes a supply tube, a straight, precisely bored tubular section, and a flow-directing insert. The insert is placed inside the tubular section. The supply tube (omitted from the figure) is welded to the upstream end of the tubular section.

The gas/liquid mixture to be used for cleaning is pumped through the supply tube and into the tubular section; it is initially directed radially outward by the insert. The flow is thus compressed by the insert until it reaches the largest diameter of the insert, where it reaches the speed of sound. As the flow continues, it is allowed to expand and accelerate to supersonic speed. The flow leaves the nozzle with a radially inward component of velocity; in other words, the flow converges upon itself and thus becomes more concentrated. This concentration greatly increases the ability of the flow to remove contaminants.

A nozzle of this type operates with a much smaller volumetric rate of flow of solvent than does a comparable nozzle used in a high-pressure liquid spray. Unlike a solvent flush, it is not necessary to use a powerful solvent when cleaning with a nozzle of this type: instead, the cleaning process relies on the mechanical action of the jet generated by the nozzle.

In comparison with a DeLaval nozzle, a nozzle of this type is much more effective in removing contaminants. The flow from a nozzle of any of the types used previously (including high-pressure-liquid nozzles and DeLaval supersonic nozzles) spreads out and is weakened after it leaves the nozzle. In contrast, the flow from a nozzle of the present type reaches its greatest concentration a short distance downstream of the nozzle outlet, so that the intensity of the jet is greater than that from a DeLaval nozzle fed at the same pressure and flow rate. Yet another advantage of this design is that it eliminates the very difficult internal machining needed to fabricate a DeLaval nozzle.

This work was done by Raoul E. Caimi and Eric A. Thaxton of **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.* *KSC-11883*

Advanced Rigid/Inflatable Spacecraft Habitation Module

This module is especially well suited to long spaceflight.

Lyndon B. Johnson Space Center, Houston, Texas

A large, lightweight, economical, easy-to-manufacture human-habitation module that is well suited to long-term use in outer space has been developed. Modules like this one have potential for commercial applications, including the provision of human habitats for the commercialization of outer space and for shelter against such hostile environments as frigid polar regions, high altitude (airborne or on mountains), and underwater. For government purposes, a module like this one can serve as a "TransHab" (a human-habitation module for transit from the surface of the Earth to low orbit around the Earth), or as a habitation or laboratory module on the International Space Station, the surface of Mars, or the surface of the Moon. Indeed a module like this one could eventually be used as a free-flying laboratory in which to conduct long-duration outer-space research.

The volume of the module is 500 m^3 (approximately twice that of the space shuttle payload bay) and can easily be increased. The module is a hybrid of an inflatable shell with a hard central structural core — an advanced structure that exploits the packaging and mass efficiencies of its inflatable structure, and the advantage of preintegration afforded by a hard-structured habitat.

Heretofore, human-habitat modules have included such hard, metallic structures as those of the Skylab, *Mir*, and other missions. Unfortunately, the designs of these modules have been constrained by considerations of weight and cost. They have also been subject to volume constraints: Because each such habitat module was built from a metallic primary structure, its usable volume was limited because a payload must fit within a specified launch rocket. Hence, whenever mission requirements dictated the need for a large usable volume that exceeded the capability of existing launch rockets, a common solution was to design new launch rockets and facilities. This solution significantly increased the cost associated with unique missions and gave rise to large financial investments in single-use vehicles. Moreover, to counteract the inherent tendency of large structures toward dynamic-load-amplification and buckling failure modes, it was necessary to make these structures even heavier. The resulting increases in weight drove launch-rocket requirements and further exacerbated the problems of the development and costs of new launch rockets.

The present advanced rigid/inflatable hybrid spacecraft habitation module is the product of an attempt to overcome the disadvantages of prior designs. This module contains a fully closed regenerative life-support system, wherein all air and water are reused. Other features of the module include thermal control; crew accommodations; protection against ionizing radiation; avionics; electronic circuitry for command, communications, and control; guidance and navigation equipment; protection against meteoroids and orbital debris (M/OD protection); and an airlock for entry and exit by the human inhabitants. All of the equipment systems that implement these

features are stored on lightweight, removable structural shelves, which, collectively, constitute a major structural component of a central structural core.

Prior to launch, an inflatable shell, with an attached M/OD protection, is collapsed and folded around the central structural core. The entire structure is then ready to be strapped onto a lightweight composite carrier that is, for present purposes, held in the space-shuttle payload bay by payload-retention latches. The space shuttle then transports the module to low orbit around the Earth. Once in orbit, the module is removed from the payload bay and its inflatable shell with M/OD protection inflated to full volume. Once the shell is fully inflated, the various systems and subsystems (e.g., food, crew accommodations, avionics, and the like) that have been stored on the lightweight structural shelves are repositioned to the internal configuration required for a Mars TransHab, the International Space Station, or other application.

As the advanced rigid/inflatable hybrid module has been described thus far, it can readily be seen to offer advantages, over older modules, of lighter weight, larger volume, greater ease of fabrication, and associated lower cost; these advantages are expected to ensure the leading role of modules like this one in long-duration spaceflight. It also offers the additional advantage of reconfigurability. Moreover, notwithstanding its inflatability, the shell is sufficiently thick and stiff that it would maintain its inflated shape in the event of a sudden depressurization.

This work was done by William C. Schneider, Horatio M. De La Fuente, Gregg Edeen, Kriss J. Kennedy, James Lester, Linda Hess, Chin Lin, and Richard H. Malecki of **Johnson Space Center** *and Shalini Gupta of Lockheed Martin.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22900.

Parabolic Membrane-Thickness Variation for Inflatable Mirror

The inflated mirror would closely approximate the desired surface figure.

NASA's Jet Propulsion Laboratory, Pasadena, California

According to a proposal, membranes to be used in inflatable focusing mirrors (see Figure 1) would be designed and fabricated with parabolic radial variations of thickness. More specifically, for a mirror membrane with a diameter D, the thickness (t) at a given radial distance (r) from the optical axis would be given by

$$t = t_0(1 + Au^2),$$

where t_0 is the thickness at the center, A is a parameter described below, and $u \equiv 2r/D$. The reason for this proposal is that by suitable choice of A, one could ensure that upon inflation, the membrane would assume a shape that closely approximates a paraboloid — the shape required for focusing in many applications.

Past investigations of membrane mir-

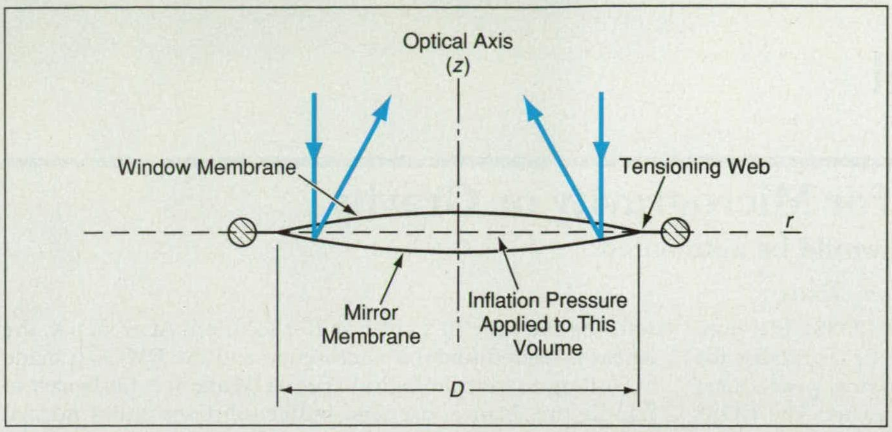


Figure 1. **Two Membranes** would be joined at an outer circular edge of diameter D, and the space between them would be pressurized. The upper membrane would be transparent and would serve as a window. The lower membrane would be coated with a reflective material and would serve as a focusing mirror.

rors have led to the conclusion that they are not suitable for imaging in visible light because their shapes when inflated differ too much from paraboloids. In particular, upon inflation, a previously flat membrane of uniform thickness assumes an oblate spheroidal shape described by a function named the "Hencky curve" after its discoverer. Although there have been suggestions that radial variations in thickness might result in inflated shapes that equal or closely approximate paraboloids, the necessary variation in thickness has not been published until now.

The proposal is justified by a mathematical derivation that starts with the classical equation for the axial deflection $[z(u)]$ of an initially flat, elastic, thin plate (that is, membrane) of thickness $t(u)$ that is subjected to a differential pressure and restrained by a ring as described above. The problem is to find $t(u)$ such that $z(u)$ would approximate the desired paraboloidal form to the desired degree of precision. The solution involves a numerical integration that leads to the conclusion that a parabolic radial variation of thickness with $A = 0.42$ would yield the desired inflated shape, regardless of the values of inflation pressure, deflection at the center, and focal ratio of the inflated membrane mirror.

A membrane according to the proposal could be fabricated most conveniently by either of two techniques. One way would be to cast or otherwise form a membrane polymer on a convex spherical mold with a large radius of curvature that yields an acceptably close approximation to the desired shape. The other way would be to adapt a technique that has been used before to make astronomical mirrors: This technique is based on the fact that the height of a liquid on a horizontal, flat, steadily rotating table varies parabolically with radius from the axis of rotation. The table would be covered with a flat disk of glass or other smooth material, a dike to contain liquid would be placed around the periphery of the disk, the required amount of monomeric liquid would be poured onto the disk, and the disk would be set into rotation at the speed necessary to make the thickness of the liquid at the planned outer diameter of the membrane equal to 1.42 times the thickness at the axis of rotation (see Figure 2). The monomer would be polymerized as the table continued to rotate, thereby locking in the parabolic radial variation with thickness.

This work was done by Aden Meinel and Marjorie Meinel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at*** *www.nasatech.com under the Mechanics category.* NPO-20952

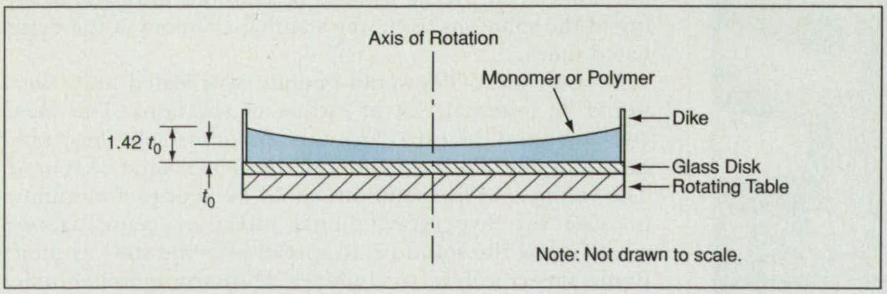


Figure 2. A **Rotating Table** would be used to form a monomeric liquid to the required parabolic radial variation of thickness, then the liquid would be polymerized. For clarity, the thickness is exaggerated in this view.

Slide-Staining System for Microgravity or Gravity

Much of the cell-staining process would be automated.

Lyndon B. Johnson Space Center, Houston, Texas

The centrifuge-operated slide stainer (COSS) is a conceptual self-contained system that could be attractive for use in a variety of histological and cytological procedures in both microgravity and normal Earth gravity. The COSS was conceived specifically for use in staining blood smears on glass slides in order to enable differential white-cell counts (DWCCs) on astronauts during spaceflight. (The differential white-cell count is a standard technique for distinguishing between a healthy condition and any of a number of viral or bacterial infections.) In addition to overcoming microgravitational obstacles to the staining process, the COSS would do most of the routine and tedious processing steps that heretofore, have been performed manually in conventional terrestrial preparation of blood samples. On Earth, the COSS could be useful at remote medical research field stations, military field hospitals, and biomedical research facilities.

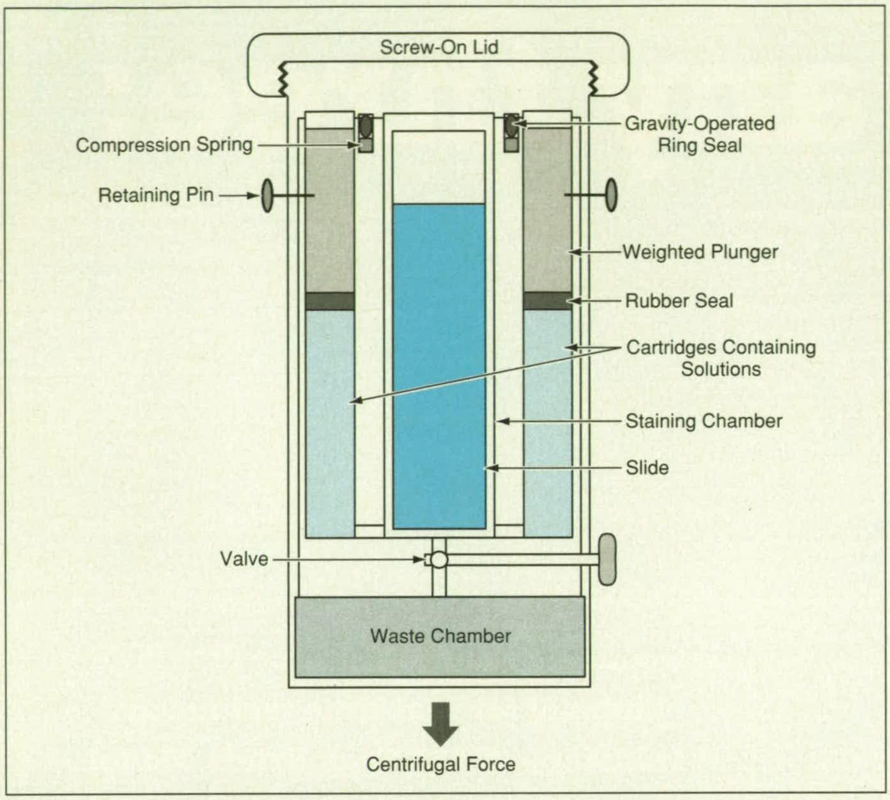
In a terrestrial setting, preparation of a sample of blood for a DWCC involves (1) smearing blood on a glass slide, (2) fixing the cells in the smear to the surface of the slide, (3) staining the cells with a histochemical stain, and then (4) washing the slide in a clean buffer solution. After step 4, the smear is viewed under a microscope and the DWCC is made according to morphological criteria. While it is fairly easy to handle the fixative, dye, and buffer solutions under normal Earth gravitation, the difficulties of handling these or any liquids in microgravity makes it impractical to perform DWCCs in spaceflight. Several prior cell-staining apparatuses have been developed for use in microgravity, but have proved inadequate for various reasons.

The design of the COSS would not only largely automate the staining process but would also eliminate the liquid-handling difficulties through the elimination of microgravity: as the term "centrifuge-operated" suggests, the COSS would be mounted in a standard laboratory centrifuge and would be operated only during operation of the centrifuge. The COSS (see figure) would comprise a cell-staining apparatus within a sealed shell. All the required fixer, buffer, and staining solutions would be contained in disposable cartridges that would be sequentially emptied into a staining chamber by centrifugal force. The sequential emptying of cartridges would be triggered by the timed removal of retaining pins from weighted plungers.

Air displaced from the staining chamber would be vented to the space previously occupied by each cartridge plunger. After the sample had been exposed to each solution, that solution would be drained from the staining chamber, into a disposable waste container, by activation of a one-way valve at the base of the staining chamber. Air displaced by draining would be vented back to the staining chamber. After each draining, the one-way valve to the waste chamber would be closed to enable filling the chamber with the next solution. During operation, air would be vented within the centrifuge via a gravity-operated ring seal valve; this valve would be open during a centripetal acceleration greater than normal Earth gravitation and would close upon return to microgravity once the centrifuge stopped spinning.

The COSS could be operated relatively easily, with minimal training and minimal human intervention. The only action required of the operator would be to place a blood-smear slide into the staining chamber, sealing the COSS shell, placing the COSS in the centrifuge, and switching on the centrifuge. The COSS would contain a microprocessor that would control the releases of solutions into, and draining of the solutions from, the staining chamber at the designated times.

Because the COSS would operate as a sealed unit, there would be minimal risk of escape of solutions. The waste container and the cartridges containing the solutions could be disposable. The remainder of the COSS could be reused. The volumes of the solutions could be kept to a minimum because the hypergravitational effect of centrifugation would cause the solutions to spread over the slide as intact liquid sheets without air bubbles. Minimization of volumes of solutions is desirable aboard spacecraft for minimizing the mass of material that must be lofted and the amount of



The **Centrifuge-Operated Slide Stainer** is depicted here in a simplified, partially schematic cross section.

waste material that must be stored after use. Minimization of volumes of solutions is also desirable in terrestrial applications in which the required solutions are very expensive. The "hands-free" aspect of the preparation of DWCC blood smears by use of the COSS would make the COSS attractive for use by nontechnical personnel at remote medical facilities.

This work was done by Daniel L. Feeback of **Johnson Space Center** *and Mark S. F. Clarke of University Space Research Association. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Bio-Medical category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Mark S. F. Clarke, Ph.D.
University Space Research Association, DSLS
3600 Bay Area Blvd.
Houston, TX 77058

Refer to MSC-22949, volume and number of this NASA Tech Briefs *issue, and the page number.*

New on the MARKET

Computer Enclosure

Rittal Corp., Springfield, OH, offers the Optipanel enclosure for computer components such as flat panels. The enclosure provides a 3.9" installation depth for commonly used front panels and plates; other installation depths include 1.97" or 5.9". Users can configure an Optipanel with an operator panel housing, mullion, rear wall, and a keyboard housing. All housings are aluminum extrusions with corner inserts and gasketing trim strips. Retaining clamps with sliding cage nuts provide the ability to install standard operator interface panels. The enclosure can be mounted on stationary pedestals or mobile bases. **Circle No. 713**

Universal Indicator

The DP3410 universal wall-mounted indicator from OMEGA Engineering, Stamford, CT, is a 6-digit industrial display indicator that measures and indicates temperature, pressure, flow, level, and other process variables. The unit provides a retransmission output and two alarm relays. An RS-485 digital communications connection can be added as an option. The indicator features an LED display, NEMA-4X wall/pipe mounted weatherproof enclosure, transmitter power supply, and analog, relay, and logic outputs. **Circle No. 714**

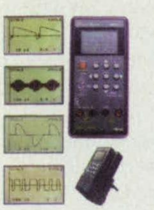
Clear Epoxy

Master Bond, Hackensack, NJ, has introduced the EP30-3 high-temperature, optically clear, low-viscosity epoxy adhesive, sealant, and encapsulant. The two-component system has a service operating temperature range of -60 to 435°F. The epoxy adheres to metals, glass, ceramics, wood, vulcanized rubber, and plastics. It resists chemicals, water, oil, fuels, and many organic solvents. The epoxy has a pot life of 12 to 18 hours and is 100 percent reactive. **Circle No. 715**

Polyethylene Films

DeWAL Industries, Saunderstown, RI, offers Uni-Pore™ porous polyethylene films with ultrahigh molecular weight for industrial and laboratory uses. The filtration and venting films provide controlled flow capabilities and high tensile strength. It is resistant to chemicals and particulate build-up, and is self-lubricating. The films are available in pore sizes from 2.5 to 50 microns, and are FDA-compliant for food, drug, and medical applications. **Circle No. 716**

Digital Oscilloscope



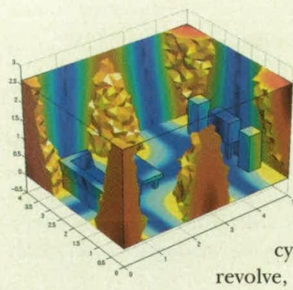
The HH972 handheld digital storage oscilloscope and in-circuit component curve tracer from Allison Technology Corp., Rosenberg, TX, provides two test instruments in one package. The oscilloscope mode features full auto-ranging, and the curve tracer mode displays I/V curves for in-circuit component testing. The instrument offers 5-MHz bandwidth, 9V battery or AC wall power, a back-lit LCD display, and keypad control. Other features include display of amplitude, time, and resistor value; test leads; and an optional stand with rechargeable battery. **Circle No. 717**

New on DISK

Digitizing Software

Renishaw, Hoffman Estates, IL, has released Tracecut Version 23 digitizing software that includes an optional surfacing module capable of creating CAD surfaces for export to any system in IGES or STL formats. Other features include 2.5D profiling, modeling capabilities, and a module for turbine blade tip refurbishment. The TraceSurf module allows seamless transfer of digitized data to CAD systems using a triangulation wizard, and enables data trimming to remove extraneous areas of data, line construction, curve fitting, surface fitting, and the ability to reverse surfaces. It also can scan an object in different orientations, then merge the data to create a single model. **Circle No. 710**

Multiphysics Modeling

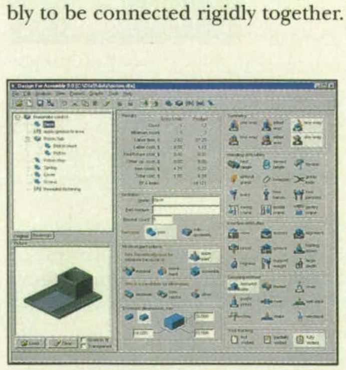


FEMLAB Version 2.0 multiphysics modeling software from COMSOL, Burlington, MA, allows users to create and analyze models in full 3D, and includes 3D primitive objects such as blocks, spheres, ellipsoids, cones, and cylinders. Commands such as extrude, revolve, and embed allow users to build 3D objects from their 2D counterparts. A new 3D Delaunay-based mesh generator allows users to control mesh size globally or selectively by subdomain, face, edge, or vertex. The software also can automatically create an animation that displays frames of a movie to illustrate dynamic effects. **Circle No. 711**

Simulation Software

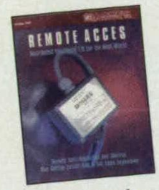
MSC.Software, Costa Mesa, CA, offers MSC.visualNastran Desktop 2001 simulation software that includes MSC.visualNastran FEA for SolidWorks (which couples solutions based on FEA technology with a CAD integrated interface) and MSC.visualNastran 4D and Motion for SolidWorks. The new products enable SolidWorks users to simulate tests before a physical prototype is made. Features include the ability to integrate MATLAB and Simulink products from The MathWorks, an iterative FEA solver, interference and proximity detection, and automatic rigid assembly mating for FEA that enables an entire assembly to be connected rigidly together. **Circle No. 709**

Assembly Design



Design for Assembly (DFA) Version 9.0 from Boothroyd Dewhurst, Wakefield, RI, features new tools that enable engineers to estimate assembly times and costs for their designs, investigate new design ideas, and select a product design from given alternatives. The software guides users through a systematic analysis of product designs, consolidating parts and eliminating assembly difficulties. A new user interface incorporates pictorial images of assembly operations and redesign suggestions. Users can define parts and assemblies by reusing design data created in PDM and CAD modeling software. **Circle No. 708**

New LITERATURE



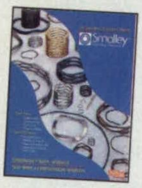
Digital I/O Devices

ACCES I/O Products, San Diego, CA, offers a 46-page catalog of REMOTE ACCES distributed intelligent I/O units. The sensor-to-computer interface units are used with digital and analog signal devices that are remote from a host computer. Digital I/O pods, analog input and output pods, accessories, serial communication cards for PCs, and other products are included. **Circle No. 720**

Flow Meters

A 120-page catalog of more than 100 flow meters and 10,000 related products is available from FloCat, Kenosha, WI. Flow metering technologies described in the catalog include magnetic, thermal mass, ultrasonic, vortex shedding, variable area, positive displacement, and differential pressure flow. Also included are flow switches and readout devices for electronic integration. **Circle No. 721**

Springs and Rings



Smalley Steel Ring, Wheeling, IL, offers a catalog of Spirawave® Wave Springs that features more than 1,000 springs in diameters from 3/8" to 16". Special designs are available up to 84" in diameter. The springs reduce spring height by 50% and maintain the deflection of a coil spring. Part listings, custom ordering information, and applications are included. **Circle No. 722**

Connector Products

The Brad Harrison® and mPm™ Designer's Guide from Woodhead Connectivity, Northbrook, IL, is a 300-page catalog of connectors, multi-ports, and related products. More than 5,500 products are featured, including cord sets, DIN connectors, and matching receptacles. The mPm molded DIN connectors and molded Brad Harrison connectors can plug into multi-port interconnection systems for a plug-and-play input and output wiring solution. **Circle No. 723**

Controls and Gages

Dwyer Instruments, Michigan City, IN, has released its 2001 catalog of controls and gages that features more than 3,500 instruments including data loggers, humidity transmitters, flow meters, pressure control and temperature instruments, and air velocity and combustion instruments. Also featured are 40 new products, as well as reference materials such as air velocity flow charts and gas conversion curves. **Circle No. 724**

Compression Limiters

A 12-page catalog from the Inserts and Tubular Products Divisions of Spirol International Corp., Danielson, CT, features compression limiters that protect plastic components of an assembly from compressive loads generated by bolt tightening. Standard inch and metric limiters are available in split seam and solid knurled types. Hole design, tightening torque, mating component materials, and the use of O-rings also are featured. **Circle No. 725**

Vol. 25, No. 1 January 2001 This form expires: June 2001

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- D ❑ Defense
- R ❑ Research Lab
- U ❑ University
- Z ❑ Other *(specify):* ____________

3 Your engineering responsibility is: *(check one)*

- A ❑ Manage Engineering Department
- B ❑ Manage a Project Team
- C ❑ Manage a Project
- D ❑ Member of a Project Team
- E ❑ Other *(specify)* ____________

4 Your job functions are: *(please check all that apply)*

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- 14 ❑ Engineering Management
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Write in the number of your principal job function ____________

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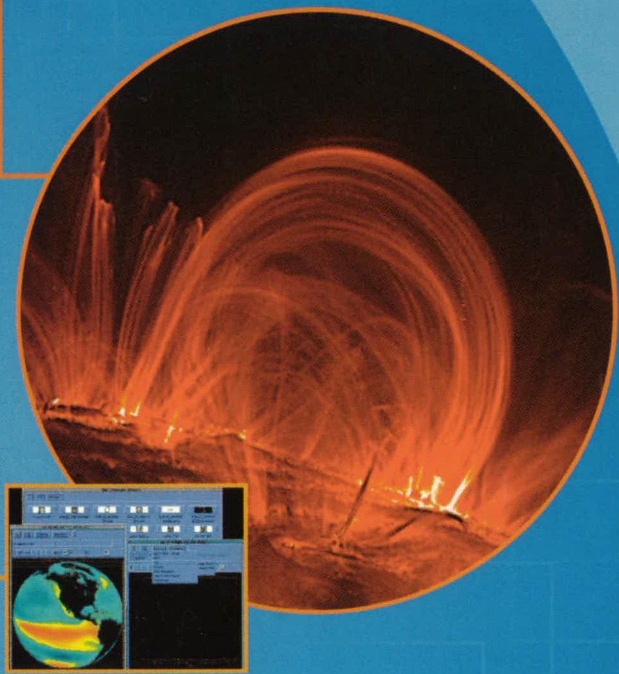

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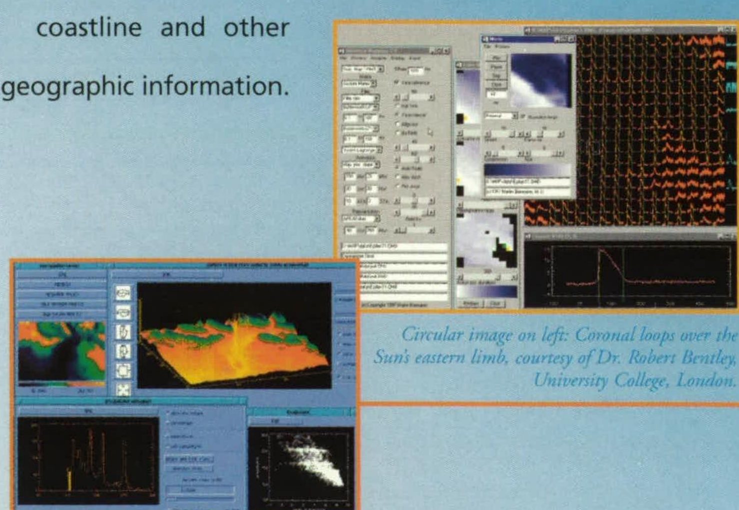

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